A MODEL FOR AUTOMATION OF PERSONNEL ASSIGNMENT

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Submitted in partial fulfillment
for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

UNITED STATES NAVAL POSTGRADUATE SCHOOL
October 1966

ABSTRACT

This thesis demonstrates the feasibility of computerized assignment of Naval enlisted personnel to fleet units. A model is constructed for determining the utility of each man for each possible ship assignment. Then various methods of assignment are investigated to find one which maximizes the summed utilities of assignment. To illustrate its capabilities, the model is then applied to several sample sets of men and ships. The authors conclude that a model of this type should be implemented in the Navy's personnel distribution system.

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1. Introduction.

> The ultimate objective of all administrative systems concerned with the movement of personnel is to maximize their utilization in the fleet. The basic aim of all personnel support systems, such as selection, classification, and training, is to ensure full utilization of personnel if at all feasible. The medium through which these ends must be attained is the fleet personnel assignment system.[3]

Under the present system of fleet personnel assignment, BUPERS assigns about twenty types of specially qualified people to fleet units. The remaining assignments are made by the Type Command Representatives (TYCOMREP) at the Enlisted Personnel Distribution Offices (EPDO). The TYCOMREP personnel assigners make their assignments on a one-at-a-time basis, using their best judgment, various thumb rules, and a number of policy and concept guidelines. Some of the man-related parameters which must be considered include personal preferences, experience, training, number of dependents, obligated service remaining, and present location of the man and his dependents. These parameters must be matched in proper sequence with the parameters descriptive of the units to which the man could be assigned. Some ship-related parameters are operating schedules, location, homeport, status of personnel requirements, and requirements unique to the particular unit. It can be seen that the task of the personnel assigner in the present system is a complex and difficult one.[12]

Since the days of "wooden ships and iron men," the Navy has grown to such magnitude in physical size, number of different types of operating units, and different skills required to operate them, that manual means of assignment are no longer acceptable. Even on a one-at-a-time basis, it would be difficult and very time consuming for an assigner to consider all pertinent parameters for each man in an objective and consistent manner. It is almost impossible to consider the array of all possible assignments, given a group of men to assign to a number of ships. But, to make the optimal set of assignments, the array of all possible assignments must be considered.

Given a number of units and a group of men to assign, it is assumed that the desirability of each possible assignment can be represented by an ordinal utility value which is useful in relating that assignment to all other possible assignments. Then, by "optimal" assignment, the available men are assigned to units in a manner such that the summed utility of all assignments is maximized. Of course, the utility of an assignment must consider both the utility of the man for the ship and the utility of the ship for the man. Maximum utilization cannot be realized unless both the ship's needs and the man's needs are considered in every case.

The determination of the utility of an assignment is a particularly difficult problem for the Navy. It might also be considered a unique problem in that the operating and deployment schedules of fleet units cause the utility of the assignment of a man to a ship to be time-dependent; i.e., the benefits a ship can derive from the assignment of any man is directly dependent upon that ship's state of operation. For example, all other things being equal, a man may be more valuable to a ship preparing for deployment than to a ship returning from deployment, or going into the shipyard for overhaul. Some time-independent parameters affecting the utility of an assignment will be discussed later in the paper.

The discussion thus far has indicated that the complexity and number of operations required in determining the utility of each possible assignment and then finding the optimal set of assignments is beyond the capability of manual methods. Therefore, the use of computer techniques is proposed as a method of solution to the assignment problem.

In a properly structured computerized assignment model, all parameters involved in all possible assignments can be considered in making the "optimal" set of assignments. Thorpe and Conner have postulated that an acceptable computerized assignment model has to meet three basic requirements: first, it has to determine for which assignments a man is eligible; second, it has to evaluate the utility value or "return" for each man in each billet for which he is eligible; finally, the assignment model has to select the set of assignments for which the total value of all men available for assignment in <u>all</u> vacant billets is maximized.[12]

These requirements constitute the basis for AUTAM (AUTomated Assignment Model), which the authors have developed and analyzed as a demonstration of the feasibility and effectiveness of computerized assignment.

2. Model.

As the name implies, AUTAM is a computerized model for assignment of personnel on the basis of utility. AUTAM is not just a theoretical exercise for computer fanatics. It is, in fact, a useful assignment model which can be implemented (with few changes) at any level of personnel administration.

In order to insure understanding at all levels, the model was kept as simple as possible. For purposes of assignment, an imaginary Type Command consisting of sixteen ships was considered. Within this TYCOM only three ratings were used: Boatswain's Mates, Quartermasters, and Signalmen. These rates were picked because they are not sensitive to Naval Enlisted Classification codes (NEC's) and thus allowed a more compact program.

As previously stated, certain man and ship parameters must be matched in proper sequence in order to determine a utility of assignment of each man for each ship. The number of parameters used in this model was kept to a minimum for the sake of simplicity. Significant omissions from the model are the man's NEC, performance evaluation, and choice of ship type. However, it was felt that the inclusion of too many parameters would only add unnecessary complexity to the model. A few representative parameters were arbitrarily chosen to show how they might be adopted to the program. Once the reader is familiar with the processing of the model, AUTAM can easily be expanded to include any parameters that might be required. The parameters considered in this model were:

Man-related: (1) Rating and pay grade.

(2) Take-up date (predicted date of reporting on board).

(3) Homeport preferences.

(4) EAOS (expiration of active obligated service).

Ship-related: (5) POB-6 (predicted on board count six months from now for a given rate and pay grade).

(6) EDP (enlisted distribution plan - number of personnel required).

(7) Homeport.

(8) Overseas deployment date.

(9) Return date from deployment.

The man-related parameters used in this model are available on the punched-card standard-format assignment deck for each man.[1] Appendix A gives a detailed description of all the man-related data that can be found on these cards. The ship-related information is readily available at all personnel distribution centers.

Having chosen the desired parameters, it was necessary to derive the assignment variables as functions of these parameters. This was accomplished by performing the man-ship matching operation which was mentioned earlier. In particular, the following relationships were examined:

(1) Man's rating and pay grade vs. ship's requirements and POB-6 in that rating and pay grade, pay grade above and/or below.

(2) Man's take-up date vs. ship deployment dates.

(3) Man's homeport preferences vs. ship's homeport.

(4) EAOS date vs. ship deployment dates.

Although the use of these variables in the model reflects the judgment of the authors, the model is not restricted to these expressed and implied judgments. The assignment "ground rules" used by any assigner or group of assigners can be applied to this model with equal effectiveness. To show how this might be done, the "assignment policy" of this model is as follows:

All other things being equal between men and/or ships, it is desirable to accomplish the following:

(1) "fill", or even "overfill" slightly, a ship preparing to deploy, in order to insure that the ship has sufficient manpower to meet its operational commitments and allow for normal manpower attrition. This policy also reduces the cost of transporting additional men overseas to the ship.

(2) insure that an assigned man has sufficient obligated service to complete the ship's next deployment.

(3) assign a man in accordance with his homeport preference.

(4) assign a man to the ship which has the smallest (POB-6)/(EDP) ratio for the rating concerned. This is the most important factor in assignment. In addition, the ratio of (POB-6)/(EDP) for the pay grade above and/or below the subject man should be considered. A man in any specific pay grade has positive utility to the ship which is short of men in the pay grade above and/or the pay grade below.

Using these criteria, the assignment variable, W_{ijk}, was computed for the assignment of the i^{th} man to the j^{th} ship as follows:

(1) W_{ij1} - Is take-up before deployment? (Parameters 2 and 8)[1]

No - 0

Yes - 1

Yes and ≤ 3 months before deployment - 2[2]

[1]The parentheses indicate which parameters are compared to determine the answer to the question. See page 13 for parameter list.

[2]The values assigned for each answer are strictly arbitrary. They reflect only ordinality of preference, not relative magnitude of preference.

(2) W_{ij2} - Is take-up during deployment? (Parameters 2, 8, and 9)

No - 0

Yes - 1

(3) W_{ij3} - Is EAOS after return date? (Parameters 4 and 9)

No - 0

Yes - 1

(4) W_{ij4} - Is ship homeport one of man's preferences? (Parameters 3 and 7)

No - 0

2nd choice - 1

1st choice - 2

(5) W_{ijk} ($k = 5, \ldots 11$) takes into account the POB-6 and EDP information. (Parameters 1, 5, and 6). For the i^{th} man's rating and pay grade, the model computes for the j^{th} ship:

$$\left(\frac{\text{POB-6} + .1}{\text{EDP} + .1}\right)_j$$

For the i^{th} man's rating and pay grade above and below, the following is computed for the j^{th} ship:

Pay grade above: $\left(\frac{P + P_A + .1}{E + E_A + .1}\right)_j$

Pay grade below: $\left(\frac{P + P_B + .1}{E + E_B + .1}\right)_j$

TABLE 1

Effect of Modification of (POB-6)/(EDP) Ratio

SHIP / PARAMETER	A	B	C	D	E	F	G
POB	1	10	0	0	1	2	2
EDP	2	20	1	2	0	0	2
POB/EDP	$\frac{1}{2}=0.5$	$\frac{10}{20}=0.5$	$\frac{0}{1}=0$	$\frac{0}{2}=0$	$\frac{1}{0}=\infty$	$\frac{2}{0}=\infty$	$\frac{2}{2}=1$
$\frac{POB+.1}{EDP+.1}$	$\frac{1.1}{2.1}=.525$	$\frac{10.1}{20.1}=.503$	$\frac{0.1}{1.1}=.091$	$\frac{0.1}{2.1}=.048$	$\frac{1.1}{.1}=11$	$\frac{2.1}{.1}=21$	$\frac{2.1}{2.1}=1$

where P = POB-6

E = EDP

SUBSCRIPT NOTATION:

A = pay grade above

B = pay grade below

none = pay grade of interest

It is noted that a constant value of 0.1 is added to both the numerator and denominator in the above ratios. The 0.1 in the denominator prevents division by zero and the same constant in the numerator allows comparisons in cases where the POB-6 is zero. Although the addition of this constant does not alter the ordinal utility of an assignment, it does bias the assignment in favor of the ship with the larger EDP. Table 1 gives examples of how the addition of the 0.1 effects the (POB-6)/(EDP) ratio. (In following these examples, the reader is reminded that a low (POB-6)/(EDP) ratio corresponds to a high utility.)

First, comparing ships E and F in the table, it is obvious that (POB-6)/(EDP) ratios cannot be computed because both ships have EDP's equal to zero. However, adding the 0.1 constant allows ratios to be determined as shown in row 4. In this case, ship F is overfilled by two men and has the higher ratio. Therefore, ship E has the higher utility and will be favored for the assignment. A comparison of ships C and D demonstrates the case where both ships have a POB-6 equal to zero. Since the ratio is again indiscriminate, the addition of the constant is needed to allow the ratios to be formed as shown in row 4.

Ship D is favored.

One final example is given to indicate how the addition of the 0.1 constant tends to bias the ratio in favor of the larger ship. In Table 1, ships A and B both have the same ratio of 0.5. However, after the addition of the constant, ship B has the lower ratio and is favored for assignment. Valid arguments can be presented both for and against this procedure. Therefore, it is hypothesized in this model that in those cases where the ratios are equal, it is better to assign to the ship needing the most number of men. To reverse this hypothesis, a small constant could be subtracted with a slight arithmetic modification. Before leaving the (POB-6)/(EDP) ratio, two more facts should be mentioned: (1) AUTAM was arbitrarily set up to compute the (POB-6)/(EDP) ratio for the i^{th} man's pay grade, pay grade above and/or pay grade below, in that order. (2) The W_{ijk} ($k = 5,6,7,8,9,10,11$) elements are designated in the model as follows:

TABLE 2

Designation of (POB-6)/(EDP) Ratio for Each Rate

i^{th} Man's Rate	Rate For Which W_{ijk} is Computed: CPO	PO1	PO2	PO3	STKR
CPO	W_{ij5}	W_{ij6}			
PO1	W_{ij8}	W_{ij7}	W_{ij9}		
PO2		W_{ij8}	W_{ij7}	W_{ij9}	
PO3			W_{ij8}	W_{ij7}	W_{ij9}
STKR				W_{ij11}	W_{ij10}

The significance of Table 2 may not be clear at this point, but it will be useful for reference during the discussion involving weighting factors for these variables.

Now that the variables have all been defined, it can be shown how these variables can be used to determine the utility of assignment of the i^{th} man to the j^{th} ship. In AUTAM, this utility is

$$u_{ij} = a_o + \sum_{k=1}^{11} a_k W_{ijk} \qquad (1)$$

where a_o is an arbitrary intercept point (10 in this model) and a_k is the weight assigned to each variable, W_{ijk}. The assumption of linearity was assumed in equation (1) for ease of computation. It was also considered that first order approximations were sufficiently accurate for this model.

The determination of the weight (a_k) of each variable is, obviously, a crucial part of the model. The concept of an effective assignment model is based on the assumption that proper weights can be found such that the generated utility of assignment, u_{ij}, reflects accurately the assignment policy desired. Since the assignment policy is based on the judgment of personnel administrators, the assignment weights must likewise be generated through repeated subjective judgments which are consistent with the policy set forth. As an illustration, it will now be shown how the weights used in this paper were determined.

Of all the variables considered in this model, the (POB-6)/(EDP) ratio is the most important. Therefore, it was used as the reference variable for determining the first rough weights. The reader is referred to Table 2 to see how the (POB-6)/(EDP) ratio for each rate is designated in the model. From this it can be seen that a good starting point might be the a_5 and a_6 coefficients. These coefficients represent, respectively, the weight assigned to the (POB-6)/(EDP) ratio for a Chief Petty Officer and the weight assigned to a Chief Petty Officer who might be utilized in a First Class Petty Officer's billet. This assumes that, other things being equal, a CPO has a greater utility on a ship which is short of PO1's than a ship which is overfilled with PO1's. This assumption was taken into account in the derivation of the W_{ijk} vectors for the pay grade above and the pay grade below. The mathematical formulation of these vectors was shown earlier.

First, a_5 was arbitrarily set equal to -5. (The negative sign is necessary to counterbalance the fact that an increase in numerical value of W_{ij5} causes a decrease in u_{ij}.) Then it was assumed that there were two ships, 1 and 2, to which the i^{th} man could be assigned. By use of an indifference comparison, similar to that used in the economic study of consumer choice, [5] values were found for W_{ij5} and W_{ij6} which caused the authors to be indifferent between assignment to either Ship 1 or Ship 2. The following is an example of this procedure:

TABLE 3

Illustrative Indifference Comparison

Trial	Ship (j)	W_{ij5}	W_{ij6}	Preferred Assignment
1	1	.7	.7	Ship 1
	2	.9	.9	
2	1	.7	.7	Ship 1
	2	.9	.5	
3	1	.7	.7	Indifferent
	2	.9	.3	

On the first trial in Table 3, the W_{ijk} values were picked arbitrarily. Since Ship 1 has a lower (POB-6)/(EDP) ratio for both CPO and PO1, it has a higher utility of assignment and is preferred for assignment of a CPO. In the second trial, the W_{ij6} value for Ship 2 was reduced to .5. However, the authors felt that Ship 1 still had preference for assignment of CPO. In the third trial, the greatly reduced ratio for PO1's on Ship 2 caused the authors to become indecisive as to which ship should be assigned an additional Chief Petty Officer. Therefore, this was the indifference point for these two variables, W_{ij5} and W_{ij6}. It should be noted that this is not a unique set of values.

Using the values from the third trial and $a_5 = -5$, the utility of Ship 1 was set equal to the utility of Ship 2 and solved for a_6:

$$u_{i1} = u_{i2}$$

$$a_5 W_{i15} + a_6 W_{i16} = a_5 W_{i25} + a_6 W_{i26}$$

$$(-5)\ (.7) + a_6(.7) = -5(.9) + a_6(.3)$$

$$a_6 = -2.5$$

With W_{ij5} as reference and a_5 still equal to -5, the values of a_1, a_2, a_3 and a_4 were determined by the same method. The results were: $a_1 = 0.5$, $a_2 = -1$, $a_3 = 1$, $a_4 = 0.5$. Since a_7, a_8, and a_9 apply only to rated Petty Officers (PO1, PO2, and PO3) and a_{10} and a_{11} apply only to Strikers, they were determined separately.[1] In this case a_7 was set equal to -5 and a_8 and a_9 were found to be -5 and -3.5 respectively. Similarly a_{10} was set equal to -5 and a_{11} was found to be -3.5. Thus far, the values obtained were:

$a_0 = 10$	$a_4 = 0.5$	$a_8 = -5$
$a_1 = 0.5$	$a_5 = -5$	$a_9 = -3.5$
$a_2 = -1$	$a_6 = -2.5$	$a_{10} = -5$
$a_3 = 1$	$a_7 = -5$	$a_{11} = -3.5$

For the purpose of allowing the utilities between different pay grades to be easily compared, the a_k (k = 5, ... 11) were rescaled such that

$$\sum_{k=5}^{6} a_k W_{ijk} = \sum_{k=7}^{9} a_k W_{ijk} = \sum_{k=10}^{11} a_k W_{ijk}$$

[1]The reader is referred to Table 2 to verify this statement.

This was done by first assuming a utility range, $0 \le u_{ij} \le 10$. Since $0 \le W_{ijk} \le 2$ for all conceivable cases, a_k was scaled such that

$$\sum_{k=5}^{6} a_k = \sum_{k=7}^{9} a_k = \sum_{k=10}^{11} a_k = -5$$

On this basis the following revised values were obtained:

$a_5 = -3.3$	$a_7 = -1.9$	$a_{10} = -2.9$
$a_6 = -1.7$	$a_8 = -1.9$	$a_{11} = -2.1$
	$a_9 = -1.3$	

Recalling that $a_5 = -5$ was used as a reference to determine a_k ($k = 1,2,3,4$), it became necessary to rescale these four coefficients in order to maintain their same relationship with a_5. Doing this: $a_1 = .3$, $a_2 = -.7$, $a_3 = .7$, $a_4 = .3$.

The procedure discussed above could be used to determine the first approximate weights for any number of variables. However, these are only approximations and must be checked by using them in the model and analyzing the results to see if the desired policy guidelines are being followed.

In this paper the initial weights were refined as follows: Using the a_k values determined above, assignment of 40 men to 16 ships was accomplished utilizing the program shown in Appendix D. This gave a sample of 640 assignments.

TABLE 4

Sample Data for Comparison of Assignments

Man	Ship	W_{ijk}, k = :												
i	j	1	2	3	4	5	6	7	8	9	10	11	u_{ij}	
1	10	0	1	1	0	0	0	.05	.09	1.48	0	0	8.86	
2	13	2	0	1	0	0	0	.05	1.00	.52	0	0	8.83	
34	13	1	0	1	1	0	0	.26	1.00	.30	0	0	~~8.62~~	8.5
22	11	0	1	1	0	0	0	.05	.52	1.00	0	0	~~8.47~~	8.6
2	16	0	1	1	0	0	0	.05	1.00	.09	0	0	8.39	
36	16	2	0	1	0	0	0	.51	.51	1.00	0	0	8.31	
1	4	0	0	1	0	0	0	.05	1.00	.52	0	0	~~8.29~~	8.1
21	2	0	1	1	0	0	0	.05	.52	1.49	0	0	~~8.02~~	8.2
34	8	1	0	1	0	0	0	.63	.80	.50	0	0	7.65	
35	11	0	0	1	0	0	0	.50	.83	.54	0	0	7.57	
33	13	1	0	1	1	0	0	.51	1.20	.44	0	0	~~7.56~~	7.6

Since those assignments with extremely high or low utility values contribute little to the refinement process, they were eliminated from the sample. Also those assignments having duplicate W vectors were eliminated. This reduced the original sample of 640 assignments to a subsample of 85 assignments. The assignment program of Appendix D was modified to give an output (on standard punched cards) of the assignment identification (number of the man and ship), the W vector describing this assignment, and the computed utility of this assignment. These punched cards were then arranged in order of descending utility value, sorted by rate group, and printed as shown in Table 4. The assignments were then compared, two at a time, to see if the assignment with the higher computed utility value was in fact preferred to the assignment with the lower utility value. Where this was not the case, the utility values were changed to reflect the disagreement with the computed utility ranking. For example, in Table 4, it was decided assignment (22,11) should have a higher utility value than assignment (34,13) because Ship 11 was lower in the rate ($W_{22,11,7}$), and rate above ($W_{22,11,8}$) comparisons. This outweighed the fact that for assignment (34,13), the man would be picked up before deployment ($W_{34,13,1}$), would receive his second choice homeport ($W_{34,13,4}$), and would alleviate a shortage in the rate below ($W_{34,13,9}$). When all assignments had been compared, the corrected utility values and the original values of the W_{ijk} variable were

TABLE 5

Weights Determined by Iteration Process

Iter. No.	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	u_{ij} changes
1	.30	-.70	.70	.30	-3.30	-1.70	-1.90	-1.90	-1.30	-2.90	-2.10	37
2	.29	-.60	.79	.32	-3.25	-1.65	-2.03	-1.81	-1.11	-2.90	-1.95	33
3	.26	-.53	.73	.30	-3.27	-1.57	-2.05	-1.77	-1.03	-3.03	-1.72	37
4	.28	-.40	.79	.35	-3.37	-1.49	-2.11	-1.80	-0.97	-3.08	-1.70	20
5	.27	-.30	.80	.33	-3.52	-1.57	-2.25	-1.92	-0.92	-3.15	-1.83	18
6	.26	-.30	.95	.33	-3.50	-1.58	-2.26	-1.94	-0.87	-3.14	-1.82	5
7	.26	-.30	1.41	.33	-3.50	-1.59	-2.27	-1.94	-0.88	-3.14	-1.82	0

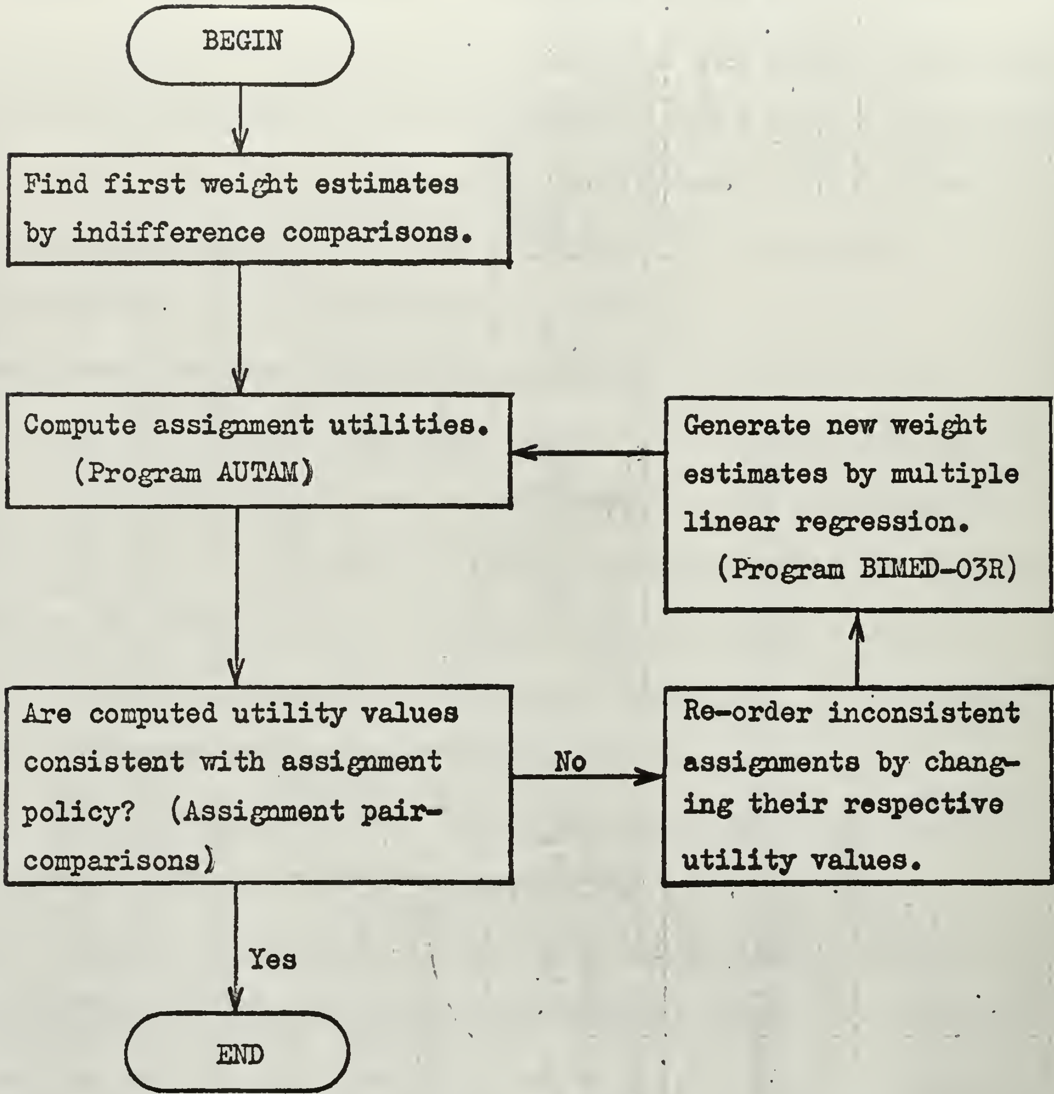

Figure 1

Feed-Back Process of Weight Evolution

then used as data input to a multiple linear regression computer program, [2] generating new weights, a_k, as the regression coefficients of the linear regression. This process was repeated until the weights obtained resulted in satisfactory assignments. For this paper, the weights were considered satisfactory when the number of utility values changed were less than 5% of the total number in the representative sample. The evolution of the weights which satisfactorily represented the "assignment policy" of the authors is shown in Table 5. Seven iterations were required. Note that 37 of 85 utility values were changed in the first iteration; none were changed in the final run.

The evolution as described, may be thought of as a "feedback" process represented as a flow diagram in Fig. 1. It is evident that much of this process depends on the judgment of the authors. However, it cannot be too strongly emphasized that the same process can be carried out by any assigner, or group of assigners, using policy guidelines determined by proper authority. [17]

After the weights of all the variables have been determined, the utility of assignment of the i^{th} man to the j^{th} ship can be found by using equation (1). All the utility values can then be arranged in an (n x m) array for the assignment of n men to m ships. Having set up the array as in Table 6, the objective is to assign the men such that the sum of the utilities is maximized. It is obvious that assignments must be made sequentially because the u_{ij} values must be recomputed after each assignment to reflect corrected POB-6 figures; i.e., the assignment of a BM1 to a ship lowers the utility of assignment of any remaining BM1, BMC, or BM2 to be considered for that same ship.

TABLE 6

Utility Matrix for Assignment

MAN	SHIP NUMBER			
	1	2	3	4
MUNYON A BM1	8.6	6.8	9.0	10.0
MULTUNAS BM2	7.3	5.4	8.3	9.4
STEVENSON BM2	7.0	5.4	8.1	10.2
WHITTLET BM2	7.3	5.4	8.3	9.4
WENGER R BM2	7.3	5.9	9.3	9.4
ANDERSON BM3	6.5	3.1	8.6	5.9
BRAINARD BM3	6.5	3.6	8.8	6.6
SANNICOL BM3	6.5	2.6	8.6	5.9
TRUJILLO BM3	6.5	3.6	8.6	6.4
COLLINS BM3	7.0	2.6	9.6	5.9
GARRIDO QM1	6.7	2.8	7.3	8.7

After the utility array has been determined, the method of assignment from this array will affect whether or not maximum utility is achieved. The classic linear programming simplex solution to the personnel assignment problem was not used because: (1) the ships have no explicit "quotas" which must be filled or cannot be exceeded, and (2) the men do not have constant utility values for all ships.

Several other standard methods exist for obtaining exact solutions to the classical assignment problem. However, the problem treated in this paper does not readily lend itself to these methods. Therefore, the authors considered methods of assignment which would:

(1) at least approximate a maximum solution.

(2) minimize computer run time.

On this basis, the following five alternative methods of assignment were investigated.

(1) Row Maximum

This was the simplest method investigated and was chosen because it was believed to most nearly simulate the manual assignment method. The i^{th} man is assigned to the j^{th} ship where i, j are determined by

$$\max_{j} u_{ij}, \; i = 1, 2, 3, \ldots, n.$$

This method looks at the first man and assigns him to the ship with the highest utility. This man is deleted from the array, the remaining affected u_{ij}'s are recomputed, and the next man is assigned in the same manner. This process is continued until all men are assigned. Using this method in the array of Table 6, MUNYON would be assigned to Ship 4, the u_{i4} for the remaining BM's recomputed, then MULTUNAS would be assigned to the ship with the highest utility value.

Appendix D shows the basic assignment program used for all five methods considered in this paper. The application of a separate subroutine for each method allows the different methods to be accomplished by the computer. In this case (Row Maximum), the subroutine in Part 1 of Appendix E is used.

(2) <u>Array Maximum</u>

This method is one step of complexity above the Row Maximum method. Instead of looking at only one row of the array and picking the maximum, this method makes the assignment of the p^{th} man to the q^{th} ship such that

$$u_{pq} = \max_{i} \max_{j} u_{ij}$$

This method makes the assignment having the highest utility in the array. The assigned man is deleted from the array, all the affected u_{ij}'s are recomputed, and the procedure is repeated until all men are assigned. In the array in Table 6, STEVENSON BM2 would be the first man assigned, and would be assigned to Ship 4.

For computer purposes, the subroutine in Part 2 of Appendix E is used for this method.

(3) <u>Row-Column Maximum</u>

This method was investigated because of the possible savings in computer time. Rather than recompute the affected u_{ij} after each assignment, this method assigns up to m men before recomputing the affected u_{ij}. The p^{th} man is assigned to the q^{th} ship if

$$u_{pq} = \max_i u_{iq} = \max_j u_{pj}$$

In this method, the first column (first ship) is looked at to see if the maximum in that column is also the maximum utility in it's row. If it is, that assignment is made and the second column is checked. If there is no row and column maximum, no assignment is made and the program goes to the next column. After all columns (ships) are checked, and the resulting assignments are made, the utilities are recomputed, and the process is reiterated until all men are assigned. In the array of Table 6, columns 1 and 2 have no row-column maximum. However, columns 3 and 4 do, and COLLINS would be assigned to Ship 3 and STEVENSON to Ship 4. Then the utilities would be recomputed before starting over.

The subroutine in Part 3 of Appendix E is used to perform this operation on the computer.

(4) Modified VAM

Vogel's Approximation Method (VAM) is a natural choice as a possible solution to this type of assignment model because it assigns sequentially and provides a solution that is usually quite close to optimum. [11] It is also a convenient method to use because it presents little programming difficulty, requires few iterative operations, and utilizes minimum-time arithmetic operations.

The logic supporting this method is that a near maximum solution should be obtained if, at each step, the man is assigned who will incur the greatest loss of utility if he is assigned to the ship having the second highest utility for him.

The VAM method, as modified for this paper, computes in each row of the utility array the difference between the maximum utility and the next highest utility. After this has been determined for all rows, assignment is made to the maximum utility in the row with the maximum difference. The affected utilities of the remaining men are recomputed and the above process is repeated until all men are assigned. As an example, applying this method to the utility array in Table 6, COLLINS would be assigned to Ship 3.

Appendix D contains the subroutine which pertains to this method of assignment.

(5) Decision Index

This method of assigning personnel has been proposed for use by the Air Force and is included for comparison. [16] It is based on the assumption that only one man will be assigned to any one job (ship). Ward has shown that the expected value of the sum of all remaining assignments is maximized by making the assignment (p, q) where DI_{pq} is the maximum value of the Decision Index array. [15]

$$DI_{pq} = mu_{pq} - \sum_{j=1}^{m} u_{pj} - \sum_{i=1}^{n} u_{iq} \qquad (2)$$

where m = number of ships

n = number of men to be assigned

u_{pq} = utility of assignment of p^{th} man to q^{th} ship

The Decision Index array is computed by use of equation (2). The assignment is made to the maximum DI, the utility array is recomputed, DI array is recomputed, and the procedure is repeated until all assignments are made. As an example of this process, the first row of the Decision Index array would be computed from Table 6 as follows:

$$DI_{11} = 4(8.6) - 34.4 - 77.2 = -77.2$$
$$DI_{12} = 4(6.8) - 34.4 - 47.2 = -54.4$$
$$DI_{13} = 4(9.0) - 34.4 - 94.5 = -92.9$$
$$DI_{14} = 4(10.0) - 34.4 - 87.8 = -82.2$$

The entire array must be computed, in the manner illustrated, before any assignments can be made. If DI_{12} is the maximum of the array, then the first man would be assigned to Ship 2.

This assignment method is accomplished by use of the subroutine in Part 4 of Appendix E.

In order to obtain data for the analysis of the five methods of assignment, each method was applied to the model, utilizing the weighting factors found earlier in the paper.

First, each method was used to assign the same sample of 50 men to 16 ships. This sample, designated Group I, was composed of 50 Boatswain's Mates of all pay grades.

TABLE 7

Group and Subgroup Average Marginal Utilities

Group	Subgroup	No. Men	Average Marginal Utility				
			ROW	ARRAY	ROW-COLUMN	VAM	D. I..
I	-	50	7.602	7.608	7.465	7.727*	7.103
II	-	50	7.584	7.526	7.592	7.635*	6.344
	A_1	25	7.666	7.607	7.647	7.686*	6.743
	A_2	25	7.529	7.577	7.574	7.554	6.148
	Over-All Ave. Marg. Utility		7.597	7.592	7.610	7.620*	6.445
	B_1	6	7.943	7.943	7.943	8.050*	7.822
	B_2	4	8.114	7.953	8.114	8.114*	6.915
	B_3	2	8.304	8.304	8.304	8.304*	7.888
	B_4	9	7.367	7.542	7.474	7.492	6.846
	B_5	7	7.769	7.818	7.767	7.818*	7.533
	B_6	12	7.614	7.621	7.616	7.622*	7.466
	B_7	3	6.764	6.811	6.764	6.811*	6.306
	B_8	7	7.441	7.417	7.441	7.455*	7.167
	Over-All Ave. Marg. Utility		7.623	7.650	7.643	7.672*	7.267

*denotes maximum in row

Then each method was used to assign another sample of 50 men to 16 ships. This sample, designated Group II, was composed of Boatswain's Mates, Quartermasters, and Signalmen of all pay grades. Group II was further subdivided into smaller sets to investigate the effect of sample size on each method of assignment. Using these subdivisions, each method was used to assign the 50 men of Group II to the 16 ships; but all the men in one subgroup were assigned before proceeding to the next subgroup. The size, number, and the results of these subdivisions are shown in Table 7. The assignments produced by each method of assignment for each sample of men were compared on the basis of average marginal utility of assignment as shown in Table 7.

The assignment utility used in the five processes of assignment is dependent on the preceding assignments; i.e., given a set of 50 assignments to make, the utility of the 16^{th} assignment depends on the preceding 15 assignments. However, the marginal utility of any assignment (as defined in this paper) depends on all 49 other assignments. This marginal utility can be computed by considering each man individually after all assignments have been made. The procedure would be to take the first assignment and subtract the man from the assigned ship's POB-6 figure. Then recompute the affected W_{ijk} variables and use these new values to determine the utility of that assignment by the procedure described earlier in the paper. Before going on to the next assignment, the POB-6 is restored to its initial value.

It is obvious that a comparison based on marginal utility of assignment is preferred because it eliminates the effects of the order in which the assignments are made. As an example, assume that three Boatswain's Mates are assigned to the same ship by different methods of assignment and that they are assigned in different order. This means that the utility of assignment of each man is different for each method. However, the marginal utility of each man, as defined above, will be identical for each of the methods. Therefore, this gives an equal basis on which to compare the five different methods of assignment.

Since Group I was composed of only one rating, a more complete set of data was obtained and is presented in Tables 8 and 9. Table 8 allows a comparison, by paygrade, of the distribution of assignment of 50 Boatswain's Mates to 16 ships. Table 9 can be used for analysis of the same set of assignments.

Analysis of the information presented in Tables 7, 8, and 9 leads to several conclusions about the different methods of assignment. Referring to Table 7, it can be noted that the VAM method made assignments which gave the maximum average marginal utility in 10 of the 12 sets of assignments which were made. This obviously accounts for the fact that the VAM method also had the highest over-all average marginal utility in both subgroups.

It can also be seen in Table 7 that the Decision Index method had the lowest average marginal utility in every case.

TABLE 8

Distribution Comparison of Five Methods of Assignment of 50 BM's

				No. Assigned by:								No. Assigned by:				
Rate	Ship No.	EDP (before assign)	POB (before assign)	ROW	ARRAY	ROW-COL	VAM	D. I.	Ship No.	EDP (before assign)	POB (before assign)	ROW	ARRAY	ROW-COL	VAM	D. I.
BMC		1	3	0	0	0	0	0		1	1	0	0	0	0	0
BM1		5	1	3	3	1	3	3		7	8	0	0	0	0	0
BM2	1	8	10	0	0	0	0	1	9	18	15	1	1	1	1	0
BM3		13	11	0	0	1	0	0		31	21	0	0	0	0	0
BMSN		1	2	0	0	0	0	0		0	2	0	0	0	0	0
BMC		1	0	1	2	1	1	1		1	1	0	0	1	0	0
BM1		5	4	1	0	1	1	2		4	3	1	1	1	1	0
BM2	2	8	9	0	0	1	0	1	10	8	9	0	0	0	0	0
BM3		13	14	0	0	0	0	0		16	10	1	1	1	1	1
BMSN		1	0	1	1	1	1	1		0	1	0	0	0	0	0
BMC		1	2	0	0	0	0	0		1	0	1	1	1	1	1
BM1		5	8	0	0	0	0	0		4	6	0	0	0	0	0
BM2	3	8	7	0	0	0	0	0	11	8	4	4	3	3	3	1
BM3		13	12	0	0	0	0	0		16	9	3	3	3	3	1
BMSN		1	0	1	1	1	1	1		0	1	0	0	0	0	0
BMC		1	3	0	0	0	0	0		1	1	0	0	0	0	1
BM1		5	2	2	3	3	2	2		4	4	0	0	0	0	0
BM2	4	8	6	2	2	2	2	0	12	8	11	0	0	0	0	0
BM3		13	8	2	2	2	2	0		16	12	0	0	0	0	4
BMSN		1	0	2	1	2	1	1		0	0	0	1	0	1	1
BMC		2	2	0	0	0	1	0		1	1	1	1	1	1	1
BM1		6	6	0	0	0	0	0		4	3	1	1	1	1	0
BM2	5	15	13	2	3	2	3	1	13	8	9	0	0	0	0	4
BM3		19	14	1	1	1	1	0		16	10	4	4	3	4	2
BMSN		0	2	0	0	0	0	0		0	1	0	0	0	0	0
BMC		2	1	1	1	1	1	1		1	2	0	0	0	0	0
BM1		6	6	0	0	0	0	0		2	2	0	0	0	0	0
BM2	6	19	18	0	0	0	0	0	14	4	3	1	1	1	1	0
BM3		31	18	2	2	2	2	1		6	7	0	0	0	0	0
BMSN		1	9	0	0	0	0	0		0	0	0	0	0	0	0
BMC		2	1	1	1	1	1	1		1	1	0	0	0	0	0
BM1		6	5	0	0	1	0	0		2	1	1	1	1	1	1
BM2	7	18	15	1	1	1	1	0	15	4	3	1	1	1	1	0
BM3		32	25	0	0	0	0	0		6	6	0	0	0	0	0
BMSN		1	1	0	0	0	0	0		0	2	0	0	0	0	0
BMC		2	1	1	1	1	1	1		1	1	1	0	0	0	0
BM1		6	8	0	0	0	0	0		2	1	1	1	1	1	2
BM2	8	18	22	0	0	0	0	4	16	4	2	2	2	2	2	2
BM3		32	24	2	2	2	2	6		6	8	0	0	0	0	0
BMSN		1	3	0	0	0	0	0		0	1	0	0	0	0	0

The utility of the remaining three methods varied with the size of the sample to be assigned. Unfortunately, the variance was not consistent and could not be defined by any of the usual mathematical techniques. Therefore, based on the data in Table 7, the highest average marginal utility was obtained when using the VAM method and the lowest when using the Decision Index method, regardless of the size of the sample. Although not presented in this paper, the authors investigated several other sample assignments. The results of this work tended to substantiate this relationship between the VAM and Decision Index methods.

Table 8 represents a detailed break-down of the assignment of Group I by each method. It can be seen that the Row, Array, Row-Column, and VAM methods effected a similar pattern of assignment distribution. For seven of the 16 ships the assignments were identical and for six other ships these four methods disagreed by only one assignment on each ship. Clearly, on the basis of this data, it is impossible to choose any one method as better than the other three. On the other hand, the pattern of distribution produced by the Decision Index method was definitely inferior to the other four methods. Some specific evidence of this poor distribution can be seen by inspection of the assignments made to Ships 4, 8, and 12. The Decision Index method did not assign nearly enough men to Ship 4 while it overfilled Ships 8 and 12. Of particular note, Ship 8 was

TABLE 9

Qualitative Parameters for Comparison of Five Methods of Assignment of 50 BM's

Quality Parameters of Assignment Methods	Method				
	Row	Array	R-C	VAM	D. I.
(1) Total No. Men Assigned	50	50	50	50	50
(2) No. Men With Take-Up $>$ 3 Mos. Before Deployment	12	13	12	18	11
(3) No. Men With Take-Up $\leq$ 3 Mos. Before Deployment	9	10	9	7	19
(4) No. Men With Take-Up During Deployment	12	11	11	9	12
(5) No. Men With EAOS After Deployment Return	50	50	46	50	49
(6) No. Men Receiving 1st HP Choice	6	7	5	7	7
(7) No. Men Receiving 2nd HP Choice	4	2	1	2	4
(8) No. Men Who Could Be Assigned to HP Preference	11	11	11	11	11
(9) Marginal Assignment Utility (Average)	7.602	7.608	7.465	7.727	7.103
(10) Assignment Utility (Average)	7.938	7.973	7.763	7.978	7.485
(11) Computer Run Time (Seconds)	135	135	158	132	143

overmanned by four BM2's and the Decision Index method assigned four more of that same pay grade. Obviously, this is an undesirable assignment pattern.

The assignment methods described in this paper each use a different procedure to assign any given group of men. Because of this fact, it is reasonable to expect that the order in which these men are assigned will differ with each assignment method. In order to investigate the effects of this ordering, Group I was assigned by each method. The results of these assignments as pertains to specific parameters is presented in Table 9.

Looking at rows (2) and (3) in Table 9, it can be seen that the Decision Index method assigned the men in such a manner that 30 of the 50 men were sent to ships preparing to deploy. Of these 30 men, 19 were sent to ships three months or less before deployment. Recalling that the authors' policy was to fill all ships preparing to deploy, the Decision Index method was the most desirable in this instance. However, looking down the list to row (4), the VAM method is favored over the other four methods in the fact that it assigned the least number of men (9) to ships which were already on deployment. Again, this is a desirable feature according to the authors' policy. At this point it might be noted that rows (2), (3), and (4) under each method do not sum to the total number of men assigned. This is due to the fact that ships which have just returned from a deployment do not have a firm date for their next deployment.

Until this date is known and can be entered into the program, men assigned to this ship do not fit into any of the categories of rows (2), (3), and (4).

The results in row (5) indicate that the Row-Column method assigned the men such that four of them were assigned to ships on which they could not complete the deployment. Clearly, this is an undesirable feature. Rows (6) and (7) show the number of men who received either their first or second homeport preferences for the ships which were considered. Based on homeport preferences, the Decision Index method is favored because it assigned all 11 men to a homeport of their choice.

Based strictly on the assignment parameters of rows (2) through (7), the Decision Index method would probably be most favored. However, when taking into account the weighting factors and the distribution of assignment mentioned earlier, row (9) shows the Decision Index method to give the lowest average marginal utility of assignment. The average assignment utility was included for the purposes of comparison [row (10)] and also shows the Decision Index method to have the lowest utility. Both rows (9) and (10) indicate that the VAM method is preferred on the basis of highest utility.

Another important consideration in comparing these five methods is the computer run time. It can be shown that the number of computer operations required in AUTAM is not a linear function of the number of ships and men, but rather a polynomial involving multiplicative terms of higher order. Therefore, although a difference in run time of five seconds may be trivial for the assignment of 50 men to 16 ships, a very significant difference in run time could result when the number of ships and men is increased for application in the fleet. In row (11) of Table 9, the VAM method is shown to have the shortest computer run time. Computer run times shown in Table 9 include program compiling time, program listing, and computation of marginal utility. By eliminating the last two items and using a binary program deck, run time for VAM was reduced to 69 seconds.

All five assignment methods were capable of performing the assignment process. However, the Decision Index method was discounted as a useful procedure because of its poor assignment distribution. Each of the other four methods was considered more effective than the manual process of assignment. Since the VAM method achieved the maximum utility and required the minimum computer run time, it was chosen for implementation into the AUTAM model as shown in Appendix D. A sample printout of AUTAM, showing only those items useful to an assigner, is shown in Appendix F. For this printout a sample of ten ships and 30 men was used.

3. Summary and Conclusions.

Briefly, the development of AUTAM was as follows:

(1) Selected man-related and ship-related parameters were compared in order to derive a set of assignment variables. These variables were used to describe the assignment function.

(2) Weights were determined for these variables in accordance with a prescribed assignment "policy."

(3) The weights and variables were incorporated into a computer program to compute the relative utility of each assignment of a given set of assignments.

(4) Methods of assignment were investigated to determine a method which would make optimal assignments and require a minimum of computer run time.

AUTAM was then derived from the computer program of step (3) combined with a modified version of the Vogel Approximation Method as applied in step (4).

AUTAM demonstrates the feasibility of computerized personnel assignment. The authors do not claim that AUTAM is the only or best method of assignment, or that the techniques employed are unique. However, it is asserted that this program is capable of duplicating any "assignment policy" formulated by authoritative sources. In comparison with the present manual methods of assignment, AUTAM, or a program similar to it, has several major advantages:

(1) Rapid. The most obvious advantage of a computerized system is that it is capable of assigning a given set of

men in only a fraction of the time required by manual methods. In addition, it could eliminate time-consuming accounting and order-writing procedures by proper integration into a centralized personnel accounting, distribution, and assignment system.

(2) Objective. A properly programmed computerized assignment process is much more objective than a qualified assigner because the computer is not subject to outside influences and personal feelings. Although it's listed here as an advantage, this cold objectivity of computerized assignment is attacked by many people on the grounds that the benefits of the "human touch" are being denied in the assignment process. In reality, all the desirable aspects of the "human touch" are included in a good assignment model. It is only the undesirable features, such as human boredom and fatigue, which are eliminated in computerized assignment. This elimination of undesirable human factors leads to the next advantage.

(3) Consistent. After determining the variables and corresponding weights which effectively describe the assignment policy, all assignments made by the computer would be in strict accordance with that policy. This process requires that the same qualitative factors be considered for each man for all possible assignments. In addition, after a specific weight has been determined for each factor, this weight must be maintained constant for all possible assignments. Certainly this is a consistency which is almost

impossible for a man to accomplish. A man can only attempt to perform the assignment task through the tedious process of repetitive subjective judgments. This very often leads to gross misuse of available manpower.

The above arguments in favor of computerized assignment are not meant to infer that skilled personnel assigners would no longer be needed. Although the number of assigners could be reduced, there would still be a requirement for handling special assignment problems. For example, it must be recognized that computers are not infallible. Therefore, each assignment should be checked by an experienced assigner. This would be a rapid spot-check for any glaring errors that would give evidence of computer malfunction. Also, the "additional information" contained on card(s) 5A of the assignment deck cannot easily be processed by the computer and may contain information which would affect the suitability of a given assignment. To more easily examine this information, it could be printed out with the computed assignment for further consideration by the assigner.

It is obvious that any assignment policy will change over a period of time. Minor changes could be reflected by an adjustment of the weight for the affected variable. However, major changes of assignment policy (usually a result of foreign conflict or other emergency) require a completely revised set of weights. In this case the entire process of the determination of weights would have to be repeated. Hopefully, this situation will not occur often.

This thesis has attempted to show that computerized personnel assignment is both a feasible and a highly desirable process. On the basis of the results obtained in the use of AUTAM, it is highly recommended that the Navy consider implementation of a program of this sort. Proper application of this program will permit full consideration of the preferences of each man to be assigned. Simultaneously, the "needs of the Service" would be considered and assignments could then be made so that the utilization of manpower would be greatly increased while taking into account the preferences of the individual.

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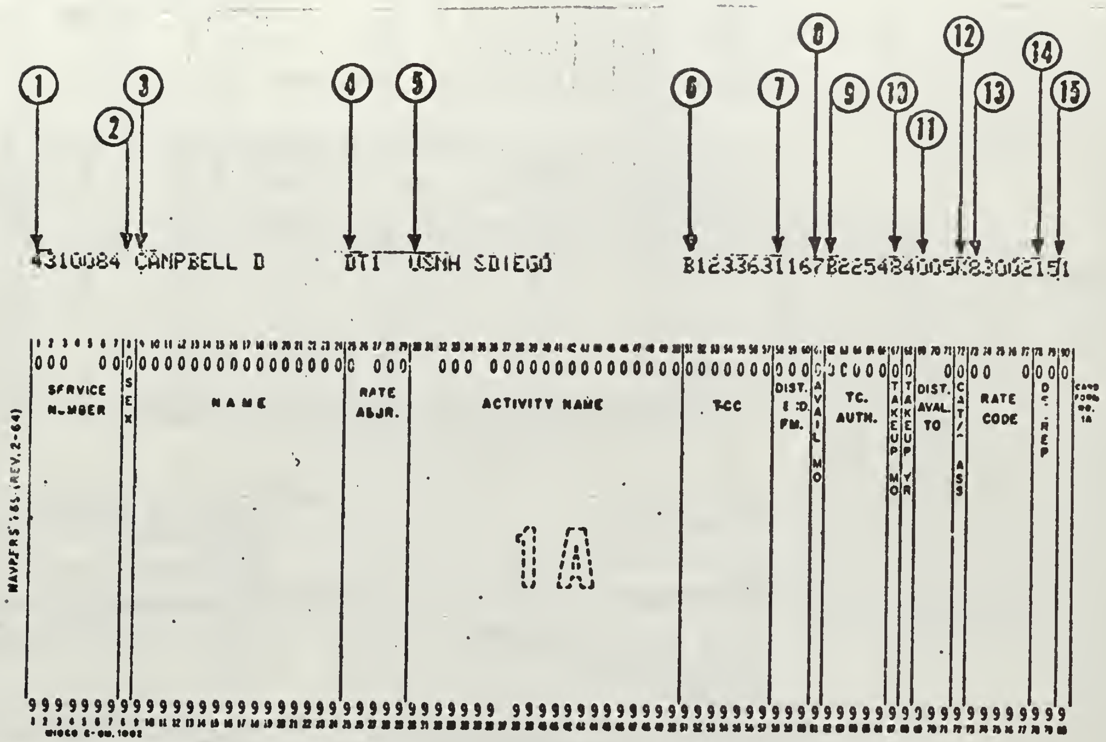
APPENDIX A

PERSONNEL ASSIGNMENT DECK



(1) Service Number.
Print positions 1 thru 7.

(2) Sex. "W" for Waves leave blank for male.
Print position 8.

(3) Surname, first name, middle initial.
Print positions 9 thru 24.

(4) Standard Rate Abbreviation.
Print positions 25 thru 29.

(5) Name of activity where the individual is stationed.
Print positions 30 thru 50.

(6) Travel Classification Code.
Print positions 51 thru 57.

(7) Distributor received from.
Refer Chapter 24 for codes.
Print positions 58 thru 60

(8) Month in which the transfer is to be executed. Refer Chapter 24 for numeric value of month.
Print position 61.

(9) Transmission Code (TC) number.
Refer Chapter 24 for TC authority codes.
Print positions 62 thru 66.

(10) Take up month and year. Estimate of month and year the individual is expected to report to new command.
Refer Chapter 24 for codes.
Print position 67 thru 68

(11) Distributor to which an individual has been made available. Refer to Chapter 24 for distributional codes.
Print positions 69 thru 71.

(12) Special Category Code. Refer to Chapter 24 for Codes.
Print position 72.

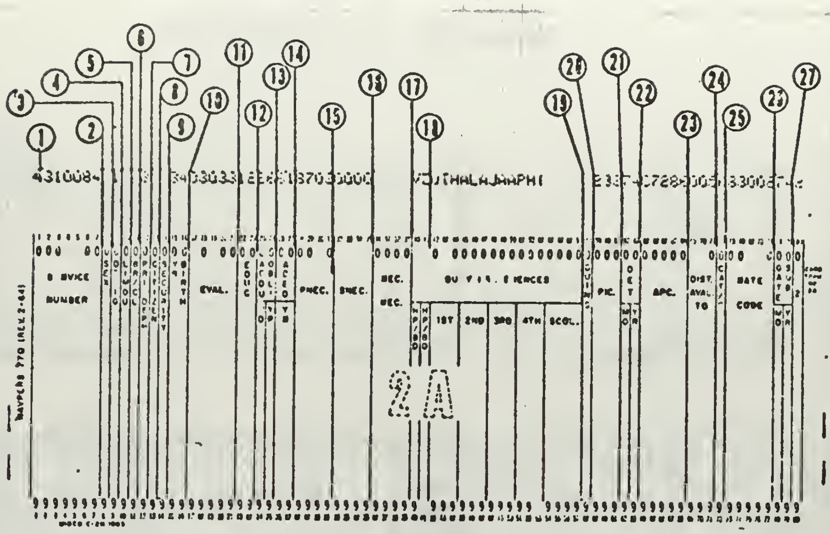
(13) Rate Code. For use by PAMI and other machine installations.
Print positions 73 thru 77.

(14) Number of days delay in reporting to count as leave.
Print positions 78 thru 79.

(15) Card number 1.
Print position 80.

Card 1A

APPENDIX A



(1) Service Number.
Print positions 1 thru 7.

(2) Sex. "W" for Waves, blank for male.
Print position 8.

(3) Enlisted designator numeric code.
Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 9.

(4) Limited duty classification code.
Blank if in all respects qualified to perform unlimited duty. Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 10.

(5) Branch and class of service code.
Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 11.

(6) Primary Dependence status code.
Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 12.

(7) Present Citizenship status.
Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 13.

(8) Type of Security Clearance held.
Refer to NMIS (NAVPERS 15,642, Part I (ACTIVE)) for Code.
Print position 14.

(9) Year of birth.
Print positions 15 thru 16.

(10) Evaluation of the individual as determined by the commanding officer and entered as a five digit code as outlined in Chapter 24.
Print positions 17 thru 21.

(11) Educational achievement.
Refer to Chapter 24 for code.
Print positions 22 thru 23.

(12) Active duty obligation. Includes reenlistment and all extensions.
Print positions 24 thru 25.

(13) Active duty base date (year).
Print positions 26 thru 27.

(14) Primary Navy Enlisted Classification, when applicable. Refer to NEC Manual (NAVPERS 15105) (series).
Print positions 28 thru 31.

(15) Secondary Navy Enlisted Classification, when applicable.
Refer to NEC Manual (NAVPERS 15,105) (series).
Print positions 32 thru 35.

(16) Recommended Navy Enlisted Classification, when applicable. Refer to NEC Manual (NAVPERS 15,105) (series).
Print positions 36 thru 39.

(17) Broad duty preferences for personnel rotating from shore to sea duty.
Refer to Chapter 25 for broad duty preference.
Print positions 40 thru 41.

(18) Four duty choices and school if desired. Refer to Chapter 25 for Codes.
Print positions 42 thru 57.

(19) "X" punch if DUINS, otherwise leave blank.
Print position 58.

(20) Purpose Identification Code.
Refer to BUPERSINST 7312.5(series).
Print positions 59 thru 61.

(21) Month and year of detachment from present command. Refer to Chapter 24 for codes.
Print positions 62 thru 63.

(22) Activity processing code entered and used only by PAMI and other machine installations.
Print positions 64 thru 68.

(23) Distributor that man is being made available. Refer to Chapter 24 for codes.
Print positions 69 thru 71.

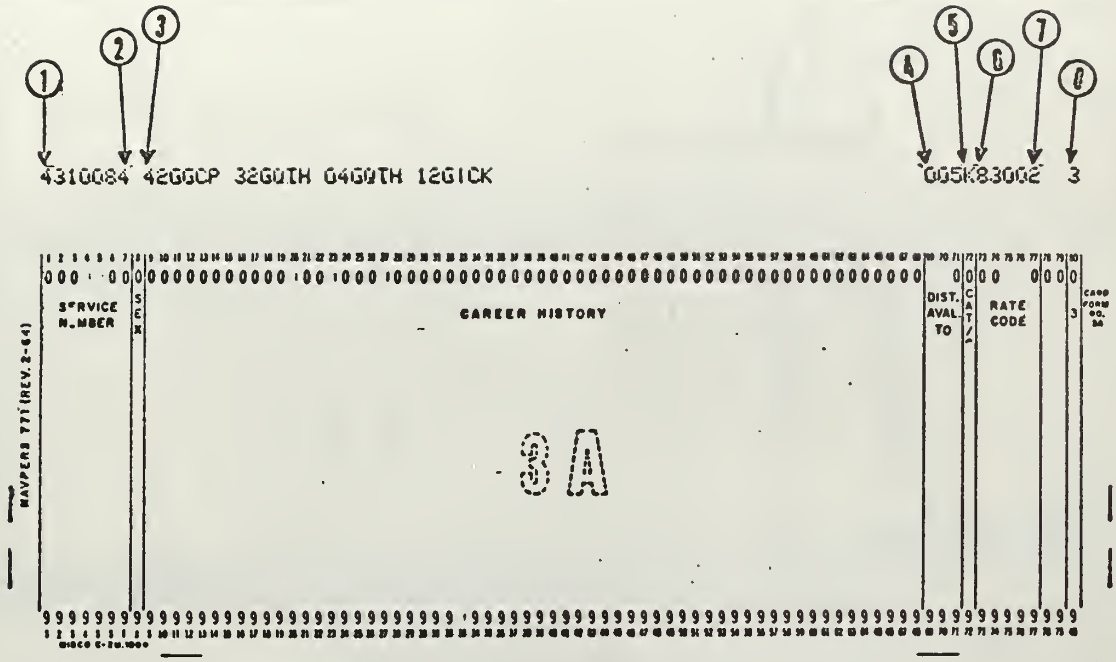
(24) Special Category Code. Refer to Chapter 24 for codes.
Print positions 72.

(25) Rate Code. For use by PAMI and other machine installations.
Print positions 73 thru 77.

(26) Date card originally submitted to BUPERS. Refer to Chapter 24 for Code.
Print positions 78 thru 79.

(27) Card number 2.
Print position 80.

CARD 2A



(1) Service number.
Print positions 1 thru 7.

(2) Sex. "W" for Waves, leave blank for male.
Print position 8.

(3) The past ten years of duty station history as transcribed from individual's service jacket. Coded in accordance with instructions contained in Chapter 24.
Print positions 9 thru 68.

(4) Distributor to which individuals has been made available. Refer to Chapter 24 for Codes.
Print positions 69 thru 71.

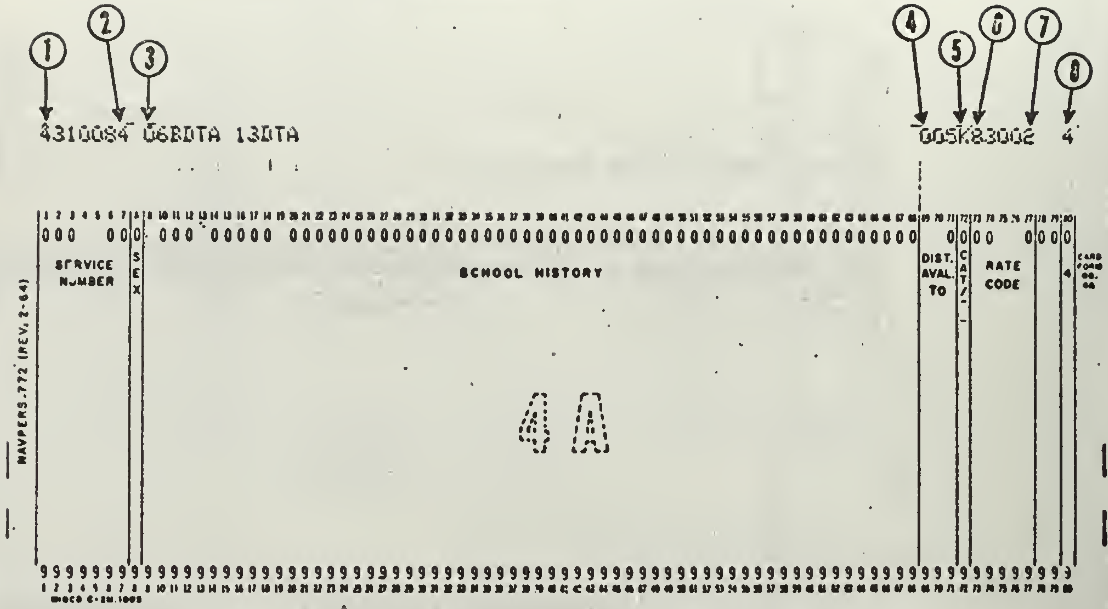
(5) Special Category Code. Refer Chapter 24 for special codes.
Print position 72.

(6) Rate Code. For use by PAMI and other machine installations.
Print positions 73 thru 77.

(7) Leave blank.
Print positions 78 thru 79.

(8) Card number 3.
Print position 80.

CARD 3A



(1) Service number.
Print positions 1 thru 7.

(2) Sex. "W" for Waves, leave blank for male.
Print position 8.

(3) Schools attended. List in inverse order of attendance. Refer to Chapter 25 for Codes.
Print position 9 thru 68.

(4) Distributor to which an individual has been made available. Refer to Chapter 24 for Codes.
Print positions 69 thru 71.

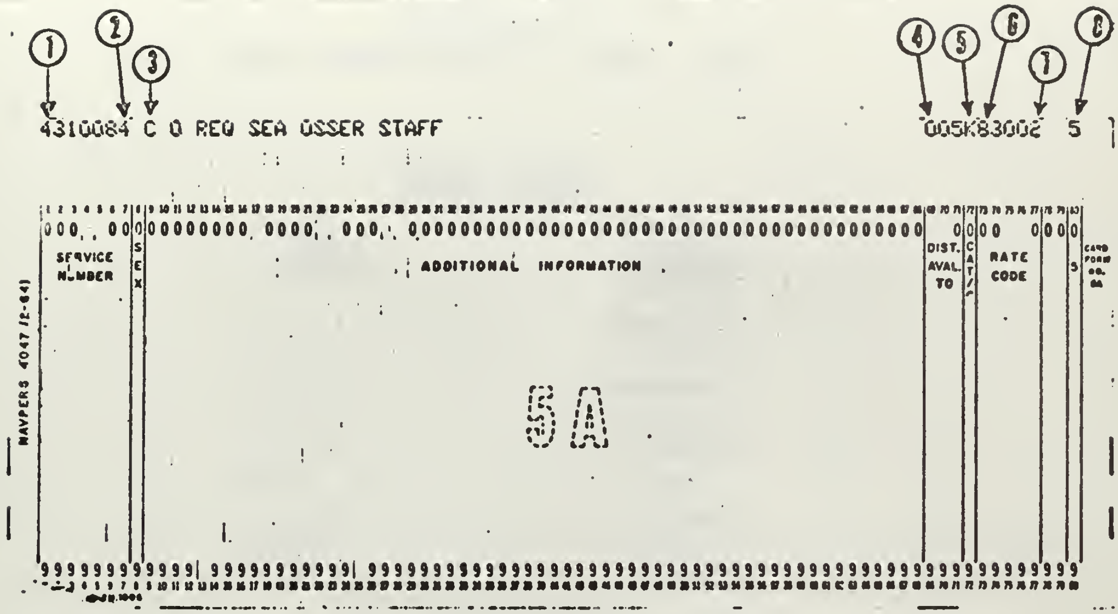
(5) Special Category Code, if applicable. Refer to Chapter 24 for special category codes.
Print position 72.

(6) Rate Code. For use by PAMI and other machine installations.
Print position 73 thru 77.

(7) Leave blank.
Print position 78 thru 79.

(8) Card number "4".
Print position 80.

CARD 4A



(1) Service number.
Print position 1 thru 7.

(2) Sex. "W" for Waves, leave blank for males.
Print position 8.

(3) Additional information
Additional comments.
Print positions 9 thru 68.

(4) Distributor to which an individual has been made available. (Refer to Chapter 24 for distributional Codes)
Print positions 69 thru 71.

(5) Special Category Code. (Refer to Chapter 24 for Codes).
Print Position 72.

(6) Rate Code. For use by PAMI and other machine installations.
Print position 73 thru 77.

(7) Consecutive card number.
Print positions 78 thru 79.

(8) Card number "5"
Print position 80.

CARD 5A

APPENDIX B

CODES USED IN ASSIGNMENT DECK

Month Codes

Month	Code
January	1
February	2
March	3
April	4
May	5
June	6
July	7
August	8
September	9
October	0 (zero)
November	J
December	B

Rate Codes

Rate	Code
BMC	01001
BM1	01002
BM2	01003
BM3	01004
BMSN	01005

APPENDIX B

Rate Codes

Rate	Code
QMC	02001
QM1	02002
QM2	02003
QM3	02004
QMSN	02005
SMC	02501
SM1	02502
SM2	02503
SM3	02504
SMSN	02505

APPENDIX B

Home Port Codes

A................ ANY PORT, ATLANTIC FLEET.
B................ NEW CONSTRUCTION, ATLANTIC FLEET.
C................ BOSTON, MASS. INCLUDES PORTSMOUTH, N. H.
D................ NEW LONDON, CONN.
E................ NEWPORT, R. I., INCLUDES QUONSET POINT, R. I., DAVISVILLE, R. I., PROVIDENCE, R. I., FALL RIVER, MASS.
F................ NEW YORK, N. Y., INCLUDES JAMAICA, N. Y., FORTSCHUYLER, N. Y., PERTH AMBOY, N. J. PORT NEWARK, N. J.
G................ PHILADELPHIA, PA., INCLUDES ATLANTIC CITY, N. J., TRENTION, N. J., LAKEHURST, N. J.
H................ WASHINGTON, D. C., INCLUDES PATUXENT RIVER, MD., BALTIMORE, MD.,
I................ NORFOLK, VA., INCLUDES NEWPORT NEWS, VA., DAM NECK, VA., LITTLE CREEK, VA., OCEANA, VA., FORT STOREY, VA.
J................ YORKTOWN, VA., INCLUDES CHINCOTEAGUE, VA.
K................ CHARLESTON, S. C. INCLUDES BEAUFORT, S. C., WILMINGTON, N. C., CHERRY POINT, N. C.
L................ JACKSONVILLE, FLA., INCLUDES MAYPORT, FLA., GREEN COVE SPRINGS, FLA., SANFORD, FLA., GLYNCO, GA.
M................ BRUNSWICK, ME., INCLUDES PORTLAND, ME.
N................ NEW ORLEANS, LA., INCLUDES PENSACOLA, FLA., ST. PETERSBURG, FLA. PANAMA CITY, FLA., MOBILE, ALA., HOUSTON, TEX., GALVESTON, TEX., PASCAGOULA, MISS.
P................ MIAMI, FLA., INCLUDES PORT EVERGLADES, FLA., KEY WEST, FLA.
Q................ CHICAGO, ILL., INCLUDES GREAT LAKES, ILL., MILWAUKEE, WISC., SHEBOYGAN, WISC., DETROIT, MICH., BENTON HARBOR, MICH., TOLEDO, OHIO, CLEVELAND, OHIO, ROCHESTER, N. Y.
R................ OVERSEAS ATLANTIC, INCLUDES ANY HOMEPORT OVERSEAS IN THE ATLANTIC OCEAN OR MEDITERRANEAN SEA.
O................ NO PREFERENCE, EITHER FLEET, ANY PORT.
S................ OVERSEAS PACIFIC, INCLUDES ANY HOMEPORT OVERSEAS IN THE PACIFIC OCEAN OR INDIAN OCEAN.
T................ ANY PORT, PACIFIC FLEET.
U................ NEW CONSTRUCTION, PACIFIC FLEET.
V................ SEATTLE, WASH., INCLUDES PUGET SOUND, WASH., EVERETT, WASH., BREMERTON, WASH., WHIDBEY ISLAND, WASH., ASTORIA, ORE., PORTLAND, ORE., TONGUE POINT, ORE.
W................ SAN FRANCISCO, CALIF., INCLUDES MARE ISLAND, CALIF., VALLEJO, CALIF., ALAMEDA, CALIF., CONCORD, CALIF., MOFFETT FIELD, CALIF., STOCKTON, CALIF.
X................ LONG BEACH, CALIF., INCLUDES SAN PEDRO, CALIF., POINT MUGU, CALIF., PORT HUENEME, CALIF., LOS ALAMITOS, CALIF.
Y................ SAN DIEGO, CALIF., INCLUDES NORTH ISLAND, CALIF., MIRAMAR, CALIF., REAM FIELD, CALIF, BROWN FIELD, CALIF.
Z................ PEARL HARBOR, HAWAII, INCLUDES BARBERS POINT, HAWAII.

APPENDIX C

DATA DECK ORDER AND FORMAT DESCRIPTION

Card No.		Description	Column No. (Inclusive)	Field Specification
1		Control Card		
		No. sets of data (NSET)	9,10	I10
		No. of ships (NSHIP)	19,20	I10
2		Ship Information (KS)		
		Hull no., name	1-16	A8
		Deploy month (code)	21	A8
		Deploy year "	22	I1
		Return month "	31	A1
		Return year "	32	I1
		Homeport "	41	A1
		Ship identity no.	44-45	I2
		(one card for each ship)		
3		EDP-POB Information		
	(a)	EDP- BMC	1-4	F4.0
		BM1	5-8	"
		BM2	9-12	"
		BM3	13-16	"
		BMSN	17-20	"
		QMC	21-24	"
		QM1	25-28	"

APPENDIX C

Card No.	Description	Column No. (Inclusive)	Field Specification
3	EDP- QM2	29-32	F4.0
	QM3	33-36	"
	QMSN	37-40	"
	SMC	41-44	"
	SM1	45-48	"
	SM2	49-52	"
	SM3	53-56	"
	SMSN	57-60	"
	Ship identity no.	69-76	A8
	(one card for each ship)		
(b)	POB - exactly same format as above		
	(one card for each ship)		
4	Weights - a_0	1-5	F5.2
	a_1	6-10	"
	a_2	11-15	"
	a_3	16-20	"
	a_4	21-25	"
	a_5	26-30	"
	a_6	31-35	"
	a_7	36-40	"
	a_8	41-45	"
	a_9	46-50	"
	a_{10}	51-55	"
	a_{11}	56-60	"

APPENDIX C

Card No.	Description	Column No. (Inclusive)	Field Specification
5	No. of men in set	9,10	I10
6	Assignment cards 1A and 2A for each man. Format in accordance with Appendix A.		

Repeat 5 and 6 for each set of men to be assigned.

```
                    SAMPLE DATA DECK FOR PROGRAM AUTAM

    DATA CARD NO. 1
--------------------------------------------------------------------------------
                          COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------

         1        10

    DATA CARD(S) NO. 2
--------------------------------------------------------------------------------
                          COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------
 USS GOLF           05        66        Y     7
 USS KILO           85        36        X    11
 USS ECHO           96        47        W     5
 USS OSCAR          85        66        Y    15
 USS LIMA           06        67        X    12
 USS JULIET         16        76        X    10
 USS HOTEL          56        37        Y     8
 USS FOXTROT        85        96        W     6
 USS DELTA          45        85        Y     4
 USS BRAVO          05        86        W     2
```

APPENDIX C

```
DATA CARD(S) NO. 3(A)

2   6  18  32   1   0   1   1   4   1   1   1   2   8   2          E 7
1   4   8  16   0   0   1   1   3   0   1   1   1   4   3          E11
2   6  15  19   0   0   1   1   4   1   1   1   1   6   1          E 5
1   2   4   6   0   0   1   0   1   0   0   1   1   1   0          E15
1   4   8  16   0   0   1   1   3   0   1   1   1   4   3          E12
1   4   8  16   0   0   1   1   3   0   1   1   1   4   3          E10
2   6  18  32   1   0   1   1   4   1   1   1   2   8   2          E 8
2   6  19  31   1   0   1   1   4   1   1   1   2   8   2          E 6
1   5   8  13   1   0   1   1   3   0   0   1   2   4   2          E 4
1   5   8  13   1   0   1   1   3   0   0   2   1   4   3          E 2

DATA CARD(S) NO. 3(B)

1   5  15  25   1   0   0   3   4   1   1   1   5   4   0          1P 7
0   6   4   9   1   0   1   0   4   1   1   1   1   6   2          1P11
2   6  13  14   2   0   1   1   8   0   1   1   4   6   0          1P 5
1   1   3   6   2   0   0   0   0   2   0   1   1   1   0          1P15
1   4  11  12   0   0   1   1   4   0   1   1   3   5   0          1P12
1   3   9  10   1   0   0   3   3   2   1   1   2   5   2          1P10
1   8  22  24   3   0   2   1   3   3   0   2   3   5   0          1P 8
1   6  18  18   9   1   0   2   3   5   0   0   3   6   1          1P 6
3   2   6   8   0   1   0   1   4   0   1   1   3   4   1          1P 4
0   4   9  14   0   0   1   0   6   1   0   1   3   7   0          1P 2
--------------------------------------------------------------------------------
                         COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------
```

```
DATA CARD(S) NO. 4
10. .26  -.3  1.41 .33  -3.5 -1.59-2.27-1.94-.88 -3.14-1.82

DATA CARD(S) NO. 5
     30
--------------------------------------------------------------------------------
                    COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------
```

APPENDIX C

```
DATA CARD(S) NO. 6

7184408 MOORE KENN        BM1  MCBASE CP LEJUN C33026     7 0502B295536403 01002151
7184408    150 29111111B84800000000     PIAS CBJYP FRA              C3302403 01002  2
4518802 MAY CHARLES D     SM2  NAVSTA SDIEGO OTH               115JP3005J5403F02503001
4518802    34003600000120765000000000000YXAD AS AR              2NBJ6C726403F02503052
3746803 TAYLOR W C        SM2  NAVSTA LBEACH   C72482BJ6 1 117JB2985J5403F02503001
3746803    12  3900000  09570000000      XVDD DLGMSOJAACSSA 2NBJ6       403F02503052
9954205 NAKAMOTO W        BM1  COMMSTA SFRISCO C76046     7 1202B295536403 01002151
9954205    120 29323411168480000000     ZWDD CAGCLGQTH              C7604403 01002  2
5400813 THOMPSON K H      BM3  NAVSTA SFRAN                 1250P3005054003Y01004001
5400813  0100041          J9590000000      Y YTBYTM            NDJ  C763840 3Y01004  2
5208925 ANDERSON W        BM3  USNH CP LEJUN NCC31366     7 0502B295536403 01004151
5208925    110 40222322B75800000000     NWDE CVAMSO                 C3136403 01004  2
5214922 HADLEY MEL        BM3  USNH SAN DIEGO  C71546     7 1102B295536403 01004151
5214922    130 413305333385800000000    YWAR AF AVSJAA              C7154403 01004  2
6865925 GIFFORD D J       QM3  TAP114 GEN WM MITCHEL        403JP2985B5403 02004151
6865925  010              17630000                                      403 02004  2
4198530 SPENCER W F       BMSN NAVSTA NORVA     C32626DJ6 1 0580B2985J5403Y01005151
4198530    13  320000012805900000000    CDAS ARCVIE                 2NDJ6C3142403Y01005052
7496933 DUDLEY DONALD E SM2   NS LBEACH OTH                 1170P2995054003Y02503001
7496933    130 353223210B75300000000    VVAGBDD ATFQTH              242957248 403Y02503052
4843735 VEGA CHARL        QM1  LSD  27 WHETSTONP40226     6 4032B295546703 02002301
4843735    130 41234211157590000000     22PHIQTHJAALFO              P4022703 02002  2
6529242 BARAN EDWA        BMC  NAS QUONSE  PT  311846     7 010BB295516403 01001151
6529242    1000221111111674200005342    UYZATFATFARSVIE             C1184403 01001  2
5659541 VILLASENOR        BM1  OTS PAS ANN LBCHC73766     7 1101B295526403 01002151
5659541 3 150 26222111177440000 5342     Y ASRARSAR JAA             C7376403 01002  2
5717256 DOWNS H P         QM2  TAP114 GEN WM MITCHEL        403JP2985B5403 02003151
5717256  015              17530000                                      403 02003  2
8735557 ENGLAND I L JR    BM3  NAVSTA ADAK                  4032P298546403 01004301
8735557  011              08                                            403 01004  2
-------------------------------------------------------------------------------
                          COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

APPENDIX C

```
DATA CARD(S) NO. 6
5879454 BROWN W G        BMSN TAP114 GEN WM MITCHEL          403JP2985B5403 01005151
5879454  011            J9600000                                       403 01005  2
5941052 DUNHAM KENNETH ESM3  NS LBEACH OTH                    1170P2995054003X02504301
5941052   100 43234531256620000000000     XWDLGCVACLG          242757248 403X02504152
6005167 STUART FRA       BM3  NAF ANDREWS AFB C85366        7 1902B29553640 3 01004151
6005167   130 21334433397490164000 0     CFDD PCSYTBSPA             C8536403 01004  2
3118164 ABRAMOWICZ       BMC  NS NEWPORT RI    C14006       7 0102B29553640 3 01001151
3118164   120 24211211107430000000 0     EEDL DD AD ITA             C1400403 01001  2
8195268 PUGH CHARL       BM3  NS WASHINGTON DCC88466        7 1901B29552640 3 01004151
8195268   130 25         7846000000000                              C8846403 01004  2
5440169 WHITTAKER J R    BMSN NAVSTA KODIAK                   4032P29854640 3 01005301
5440169  010             27              YZAD AD AS AD                 403 01005  2
2815768 GREGORY FR       BM2  ORD UN KEY WEST C45706        7 060JB2955B5403 01003151
2815768   130G31223322288520000000 0     PLAS YTMDD                 C4570403 01003  2
5201274 GARRIDO IG       QM1  DER 322 NEWELL   P64036       6 4032B29554670 3 02002301
5201274   121 41223322278590000000 0     11YOOYOOYOOMAI             P6403703 02002  2
9738474 JAMES GEOR       SM3  NAAS REAMFLD CALC70766        7 1102B29553640 3 02504151
9738474   120 40344211187580000000 0     XYCVACA DD JAA             C7076403 02504  2
5119084 TRICE ROBE       SM3  NAVFAC LEWES DELL00876        7 042JB2955B5403 02504151
5119084   110 43330111167620000000 0     WXCVACLGCAGJAA             L0087403 02504  2
3483284 HUGHES WIL       BM2  TRARON 31         C96856      7 0812B29553640 3 01003151
3483284   120 30322311127510000000 0     SWAE AR AD JAA             C9685403 01003  2
5676585 KERSON J E JR    BM1  NAVHOSP BREM                    1380P300505403Y01002001
5676585  0160028         164600000000    VVYTMYTLYTBSPA      NDJ05C8084403Y01002  2
4583793 WENGER ROB       BM2  COMMSTOR HUENEMEC71086        7 1102B29553640 3 01003151
4583793   100 36333311179540000000 0     XWDD AR AFSJAA             C7108403 01003  2
3613592 MINGUS ELM       BM1  ATF 110 QUAPAW   P14406       6 4032B29554670 3 01002301
3613592 3 140 31023333319490000 5343     11HCCHCCKLBPAC             P1440703 01002  2
9654993 OLINGER KE       BM2  U/W ORDSTA NEWPTC13166        7 0102B29553640 3 01003151
9654993   130 35324311130540000000 0     RTAD AS CAGSPA             C1316403 01003  2
---------------------------------------------------------------------------------
                          COLUMN INDEX FOR DATA CARDS
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

APPENDIX D

DESCRIPTION OF PROGRAM AUTAM

AUTAM was written in FORTRAN-63 for use on the CDC-1604 computer at the Naval Postgraduate School, Monterey. AUTAM consists of the main program, PROGRAM AUTAM; one function subprogram, FUNCTION IDA; and two subroutine subprograms, SUBROUTINE RATIO and SUBROUTINE ASSIGN. The interrelation of the main program and the subprograms is shown in the plain-language generalized flow chart in Part 1 of this appendix.

In Part 2 of this appendix, each part of the complete program is described in more detail by:

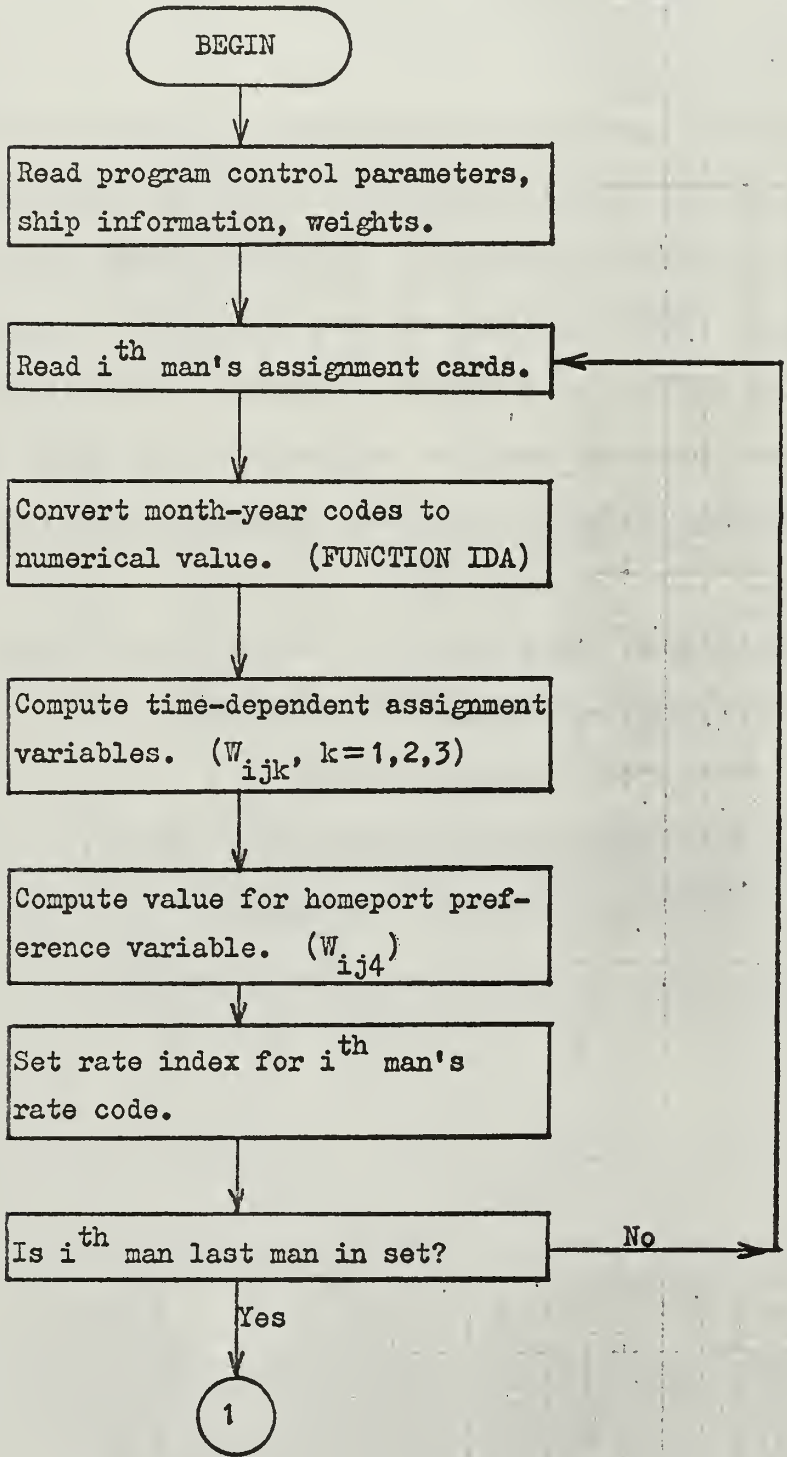
(1) Table of Variables Used,

(2) Detailed Plain-language Flow Chart,

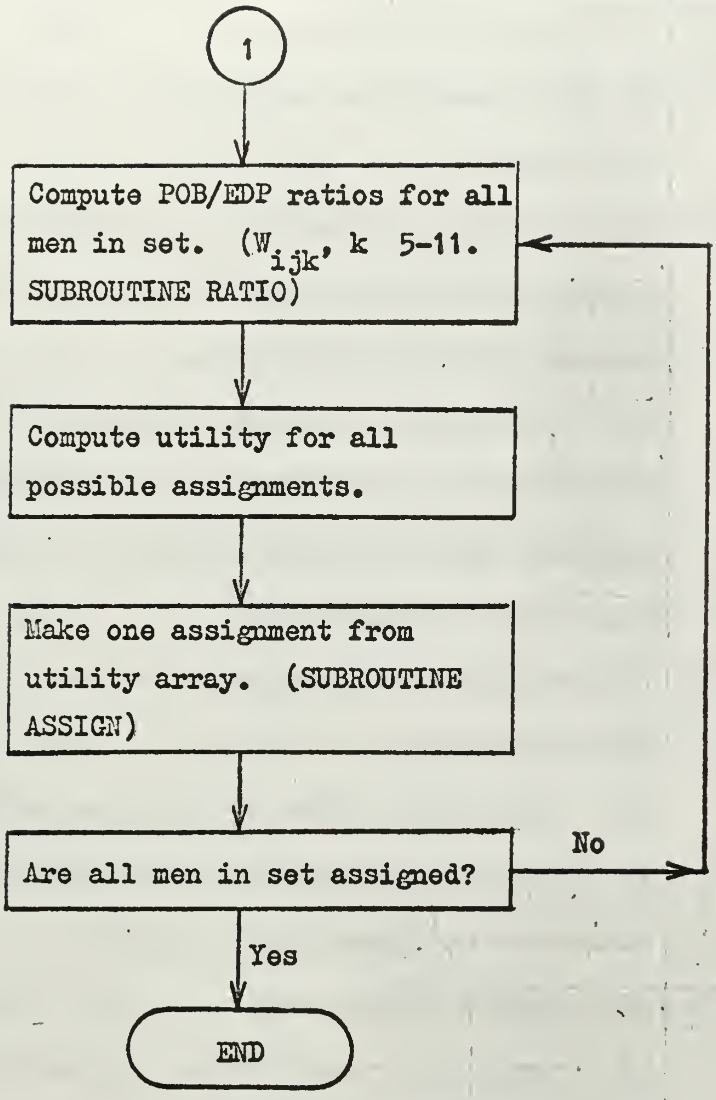
(3) FORTRAN-63 Program Listing.

APPENDIX D

Part 1. AUTAM Generalized Block Diagram



APPENDIX D


1
Compute POB/EDP ratios for all men in set. (W_{ijk}, k 5-11. SUBROUTINE RATIO)
Compute utility for all possible assignments.
Make one assignment from utility array. (SUBROUTINE ASSIGN)
Are all men in set assigned?
No
Yes
END

APPENDIX D

TABLE OF VARIABLES AND CONSTANTS IN PROGRAM AUTAM

1.	A(K)	Weight vector for assignment variable. (Constant)
2.	GR(K)	Dummy variable used in conjunction with computation of marginal utility. Contains sum of W(I,J,K) elements.
3.	I	Row subscript. Usually refers to I^{th} man.
4.	IDA	Function subprogram used to convert alpha-numeric date code to number of months from base date (January 65).
5.	ID(J)	Identifies to which ship the set of 15 EDP values belong.
6.	IK(LM)	The sequential order of assignments. (Used in comparing assignment methods, in conjunction with marginal utility.
7.	IM(I)	The number of the ship to which the I^{th} man was assigned. Zero value indicates man has not yet been assigned in assignment process. Set to 99 if I^{th} man has rate code error.
8.	IP(J)	Relates POB values to proper ship. (ID(J) and IP(J) used to insure proper or ordering of data deck.)

9.	IR(I)	A rate code index for I^{th} man. Relates his rate code to proper column in (EDP)/(POB) array.
10.	IRUN	Iteration index for number of sets of men to be assigned.
11.	I2	Iteration index for number of assignments made.
12.	ISD	Numerical conversion (by IDA) of ship's deployment date code.
13.	ISR	Numerical conversion (by IDA) of ship's return from deployment date code.
14.	ITU	Numerical conversion (by IDA) of man's take-up date code.
15.	IXE	Numerical conversion (by IDA) of man's EAOS date code.
16.	J	Column subscript - usually refers to J^{th} ship.
17.	JA,JB	Control indices for computation and recomputation of (POB)/(EDP) ratio and utility. After an assignment utility and (POB)/(EDP) ratio recomputed only for ship just assigned to.
18.	K	Element index for W_{ijk} vector describing assignment of I^{th} man to J^{th} ship.

19.	KS(I,J)	Hull no., name, deployment dates, homeport and identification number corresponding to ID(J), IP(J) for J^{th} ship.
20.	MA(I,J)	Data vector, for I^{th} man, taken from assignment deck. (Name, serial no., rate, rate code, etc.)
21.	MR(I)	Rate code table which is compared to man's rate code to find rate code index IR(I).
22.	N	Number of men in set to be assigned.
23.	NSHIP	Number of ships to be assigned to.
24.	SA(I,J)	Array of (POB)/(EDP) values for ships. (NSHIP X 30) First 15 cols: EDP Next 15 cols: POB
25	W(I,J,K)	N X NSHIP array of vectors describing assignment of I^{th} man to J^{th} ship.

9. IR(I) — A rate code index for I^{th} man. Relates his rate code to proper column in (EDP)/(POB) array.

10. IRUN — Iteration index for number of sets of men to be assigned.

11. I2 — Iteration index for number of assignments made.

12. ISD — Numerical conversion (by IDA) of ship's deployment date code.

13. ISR — Numerical conversion (by IDA) of ship's return from deployment date code.

14. ITU — Numerical conversion (by IDA) of man's take-up date code.

15. IXE — Numerical conversion (by IDA) of man's EAOS date code.

16. J — Column subscript - usually refers to J^{th} ship.

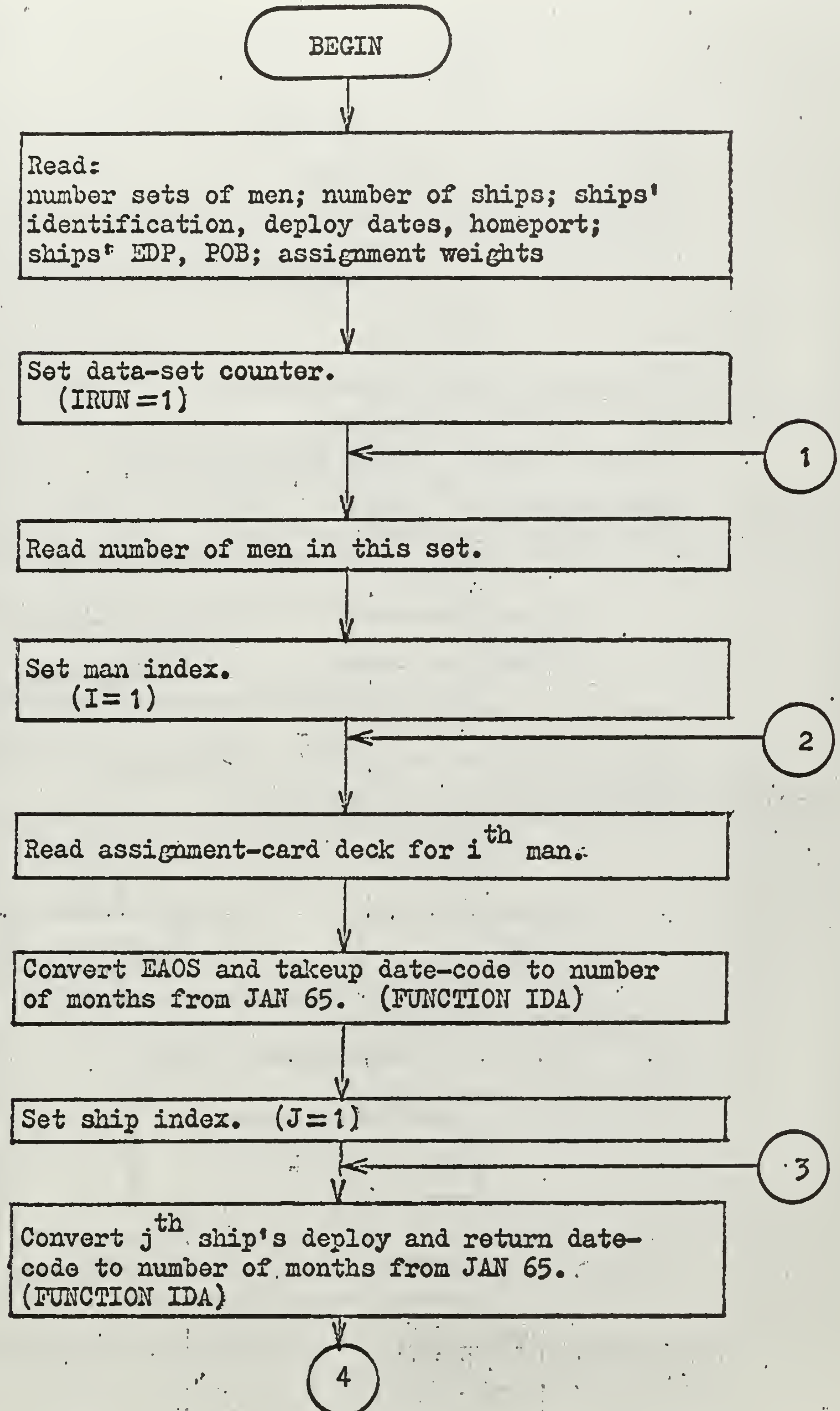
17. JA,JB — Control indices for computation and recomputation of (POB)/(EDP) ratio and utility. After an assignment utility and (POB)/(EDP) ratio recomputed only for ship just assigned to.

18. K — Element index for W_{ijk} vector describing assignment of I^{th} man to J^{th} ship.

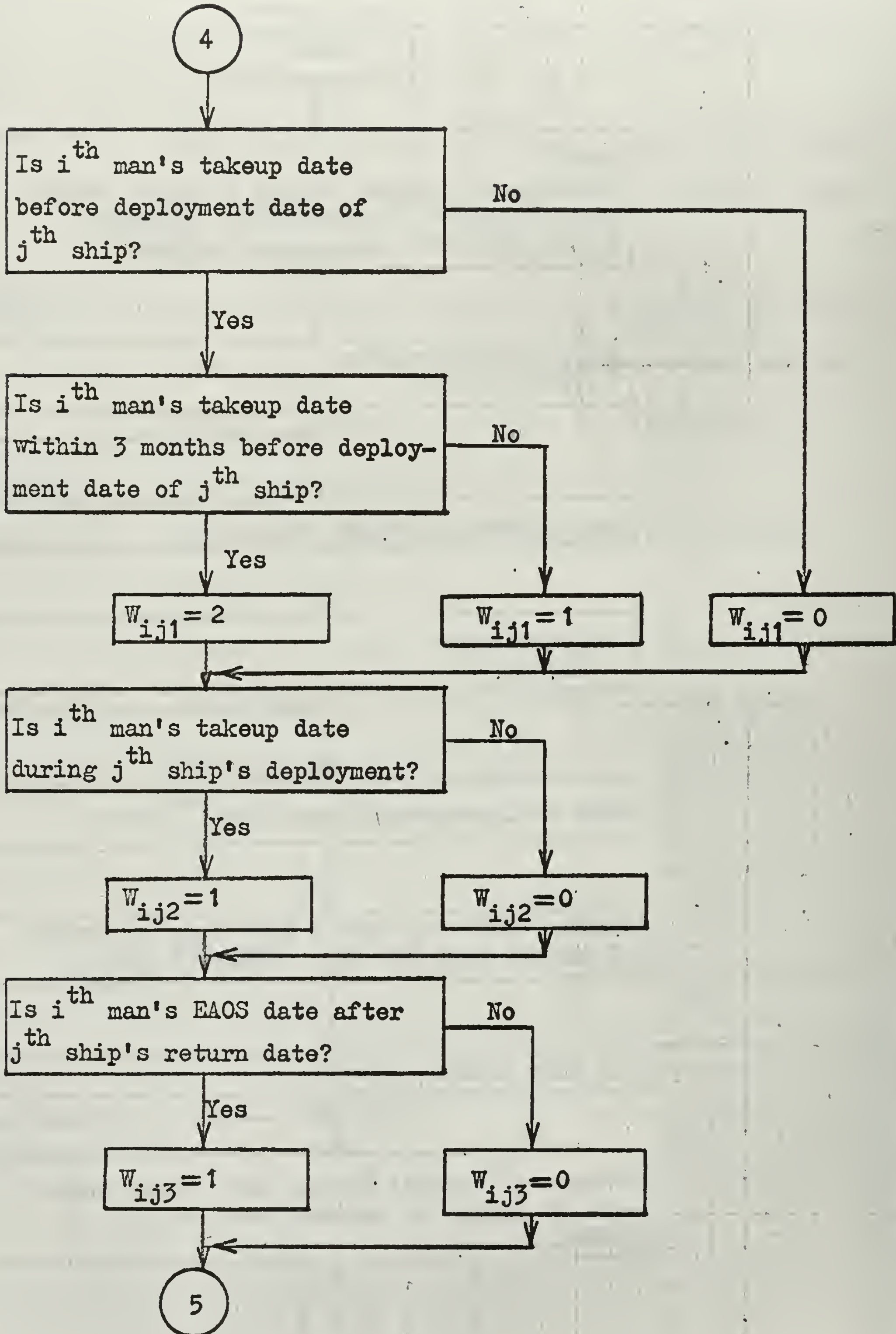
19.	KS(I,J)	Hull no., name, deployment dates, homeport and identification number corresponding to ID(J), IP(J) for J^{th} ship.
20.	MA(I,J)	Data vector, for I^{th} man, taken from assignment deck. (Name, serial no., rate, rate code, etc.)
21.	MR(I)	Rate code table which is compared to man's rate code to find rate code index IR(I).
22.	N	Number of men in set to be assigned.
23.	NSHIP	Number of ships to be assigned to.
24.	SA(I,J)	Array of (POB)/(EDP) values for ships. (NSHIP X 30) First 15 cols: EDP Next 15 cols: POB
25	W(I,J,K)	N X NSHIP array of vectors describing assignment of I^{th} man to J^{th} ship.

APPENDIX D

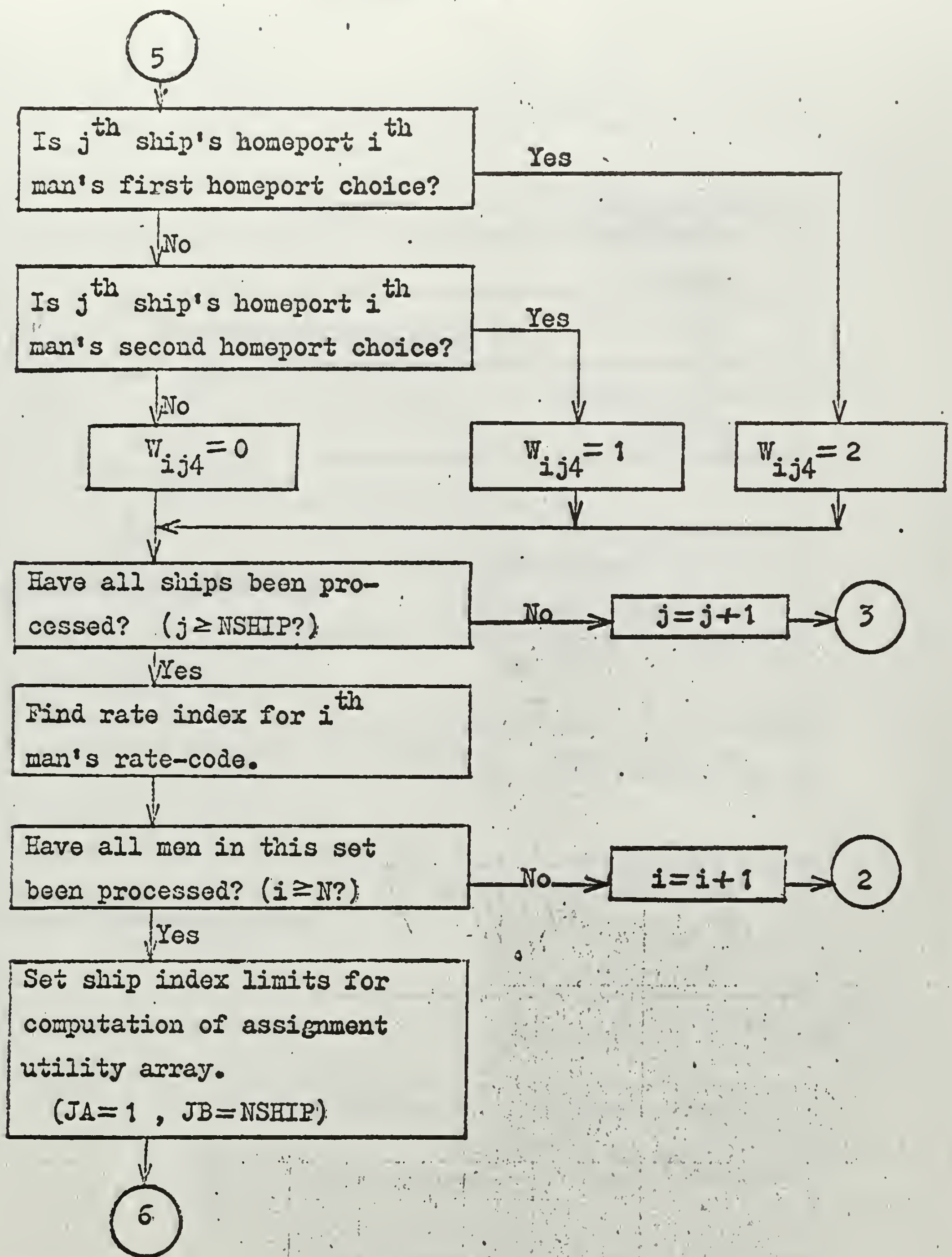
Detailed Plain-Language Flow-Chart for AUTAM



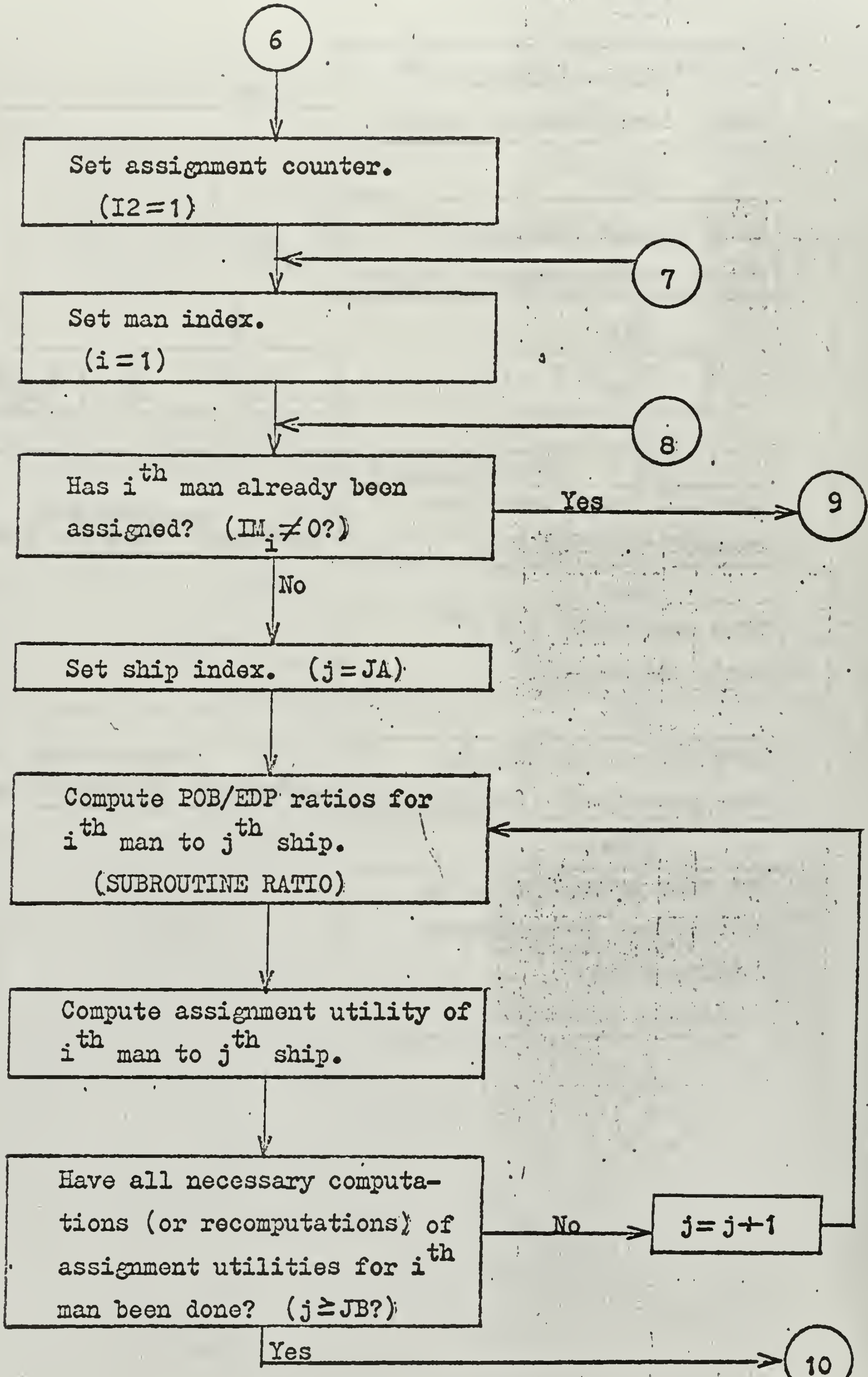
APPENDIX D


4
Is ith man's takeup date before deployment date of jth ship?
No
Yes
Is ith man's takeup date within 3 months before deployment date of jth ship?
No
Yes
$W_{ij1} = 2$
$W_{ij1} = 1$
$W_{ij1} = 0$
Is ith man's takeup date during jth ship's deployment?
No
Yes
$W_{ij2} = 1$
$W_{ij2} = 0$
Is ith man's EAOS date after jth ship's return date?
No
Yes
$W_{ij3} = 1$
$W_{ij3} = 0$
5

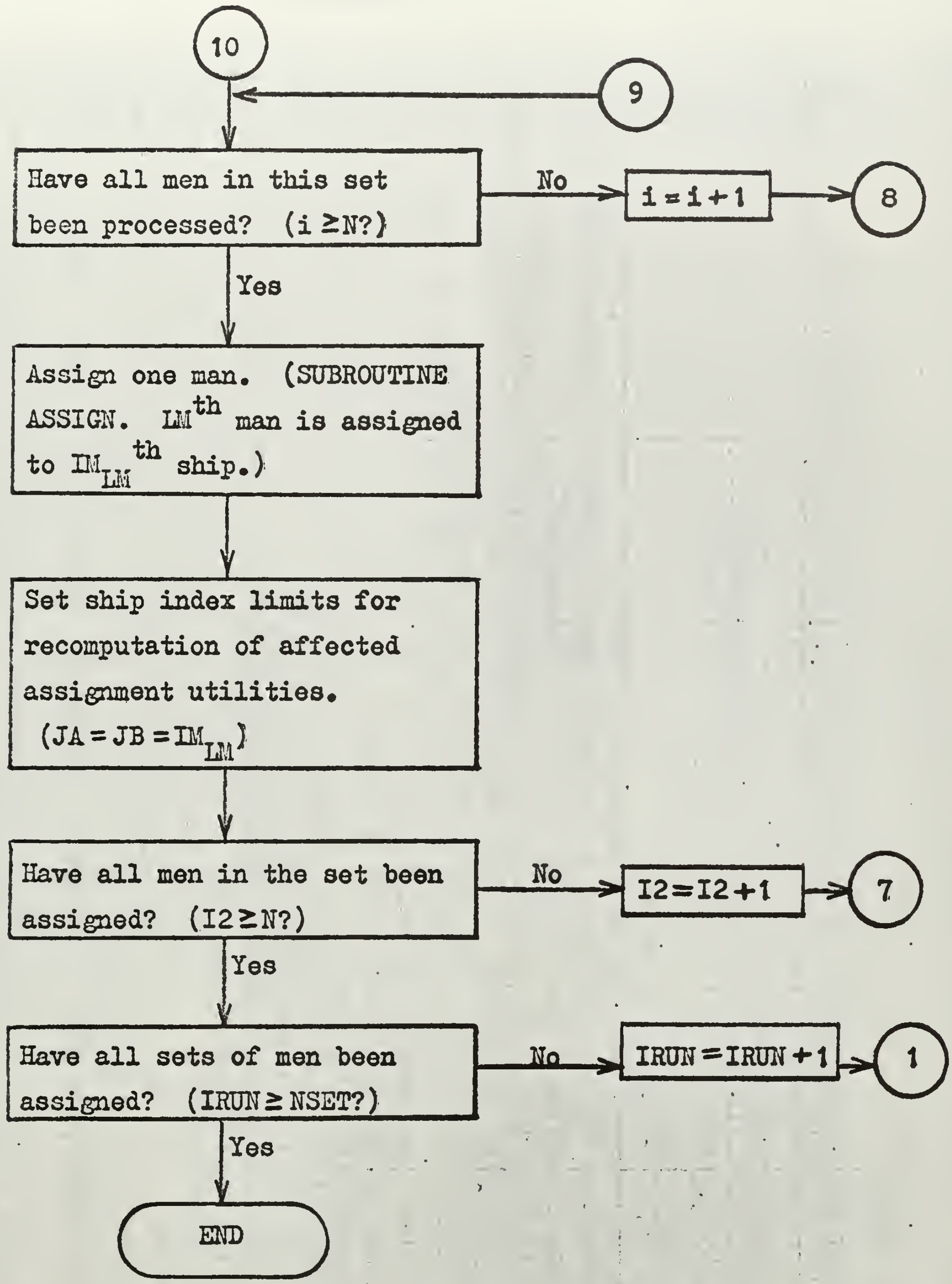
APPENDIX D


5
Is j th ship's homeport i th man's first homeport choice?
Yes
No
Is j th ship's homeport i th man's second homeport choice?
Yes
No
W ij4 = 0
W ij4 = 1
W ij4 = 2
Have all ships been processed? (j ≥ NSHIP?)
No
j = j + 1
3
Yes
Find rate index for i th man's rate-code.
Have all men in this set been processed? (i ≥ N?)
No
i = i + 1
2
Yes
Set ship index limits for computation of assignment utility array. (JA = 1 , JB = NSHIP)
6

APPENDIX D


6
Set assignment counter. (I2=1)
7
Set man index. (i=1)
8
Has i^th man already been assigned? (IM_i ≠ 0?)
Yes
9
No
Set ship index. (j=JA)
Compute POB/EDP ratios for i^th man to j^th ship. (SUBROUTINE RATIO)
Compute assignment utility of i^th man to j^th ship.
Have all necessary computations (or recomputations) of assignment utilities for i^th man been done? (j≥JB?)
No
j=j+1
Yes
10

APPENDIX D


10
9
Have all men in this set been processed? (i ≥N?)
No
i = i + 1
8
Yes
Assign one man. (SUBROUTINE ASSIGN. LM^th man is assigned to IM_LM^th ship.)
Set ship index limits for recomputation of affected assignment utilities. (JA = JB = IM_LM)
Have all men in the set been assigned? (I2 ≥ N?)
No
I2 = I2 + 1
7
Yes
Have all sets of men been assigned? (IRUN ≥ NSET?)
No
IRUN = IRUN + 1
1
Yes
END

APPENDIX D

```
      PROGRAM AUTAM
C
      DIMENSION KS(8,16),SA(30,16),W(50,16,15),IM(50),A(12),IR(50),
     1MA(50,15),ID(16),MR(15),U(50,16),IK(50),GR(50),IP(16)
      COMMON SA,W,MA,KS,U,NSHIP
      DATA(MR=01001,01002,01003,01004,01005,02001,02002,
     102003,02004,02005,02501,02502,02503,02504,02505)
C
C  NSET = NO. SETS OF DATA TO BE RUN
C  NSHIP (NO. OF SHIPS) MAX IS 16 FOR THIS PROGRAM
C  KS(I,J) INFORMATION ON JTH SHIP I=  1,HULL NO., 2,NAME,  3 -DEPLOY MO
C  4-DEPLOY YR,  5-RETURN MO,  6-RETURN YR,  7-HOME PORT
C  SA(I,J),I=1,15 = EDP FOR JTH SHIP.  I = 16,30 = POB-6 FOR JTH SHIP
C  A(K) IS THE WEIGHT ASSIGNED TO THE DECISION FACTOR W(I,J,K) FOR THE
C  ASSIGNMENT OF THE ITH MAN TO THE JTH SHIP. THE SUMMED PRODUCT
C  A(K)*W(I,J,K),K = 1, 12, DEFINES THE UTILITY OF THE ASSIGNMENT OF THE
C  ITH MAN TO THE JTH SHIP.
C  N IS NO. MEN TO BE ASSIGNED (MAX N IS 50)
      READ 49,NSET,NSHIP
      READ 10,((KS(I,J),I=1,8),J=1,NSHIP)
      READ 11,(((SA(I,J),I=1,15),ID(J)),J=1,NSHIP)
      READ 11,(((SA(I,J),I=16,30),IP(J)),J=1,NSHIP)
      READ 881,(A(K),K=1,12)
      DO 999 IRUN=1,NSET
      READ 49,N
   70 DO 89 I=1,N
C
C  IM INDICATES WHETHER MAN IS ALREADY ASSIGNED, OR HAS RATE CODE ERROR
C
      IM(I) = 0
      DO 89 J=1,NSHIP
      DO 89 K=1,15
   89 W(I,J,K)=0.
      DO 72 I=1,N
C
C  READ 1A, 2A CARD FOR ITH MAN, PERFORM ALL COMPUTATIONS AND COMPARISON
```

```
C     MA(I,J) = ALL PERSONAL INFO ON ITH MAN
C     FOR J =  1-SN,SEX,  2,3-NAME,  4,5,6-RATE AND PRESENT LOCATION, 7-TC
C     8,9-TAKE-UP DATE, 10-RATE CODE, 11-NO.DEPN., 12,13-EAOS, 14,15-HP PRE
C
         READ 2,(MA(I,J),J=1,15)
         ITU=IDA(MA(I,8),MA(I,9))
         IXE=IDA(MA(I,12),MA(I,13))
      63 DO 35 J=1,NSHIP
C
C     CONVERT YR-MO CODES TO NO. MO. FROM JAN 65
C     DATES - ISD = DEPLOY, ISR = RETURN, ITU = TAKEUP, IXE = EAOS
C
      73 ISD=IDA(KS(3,J),KS(4,J))
         ISR=IDA(KS(5,J),KS(6,J))
C
C     W(I,J,1)-IS TAKEUP BEFORE DEPLOYMENT
C
         IF(ISD-ITU)25,25,22
      22 IF(ISD-ITU-3)21,21,24
      21 W(I,J,1)=2. $ GO TO 25
      24 W(I,J,1)=1.
C
C     W(I,J,2)-IS TAKEUP DURING DEPLOYMENT
C
      25 IF(ISD.LT.ITU.AND.ITU.LT.ISR)26,28
      26 W(I,J,2)=1.
C
C     W(I,J,3)-IS EAOS AFTER DEPLOYMENT RETURN
C
      28 IF(IXE-ISR)301,30,30
      30 W(I,J,3)=1.
C
C     W(I,J,4)-IS SHIP HP ONE OF MANS PREFERENCES
C
     301 IF(MA(I,14).EQ. KS(7,J))31,32
```

```
   31 W(I,J,4)=2.$ GO TO 35
   32 IF(MA(I,15).EQ. KS(7,J))33,35
   33 W(I,J,4)=1.
C
C  MATCH MANS RATE CODE TO ROW INDEX IN SA(I,J) MATRIX
C
   35 CONTINUE
      DO 42 M =1,15
      IF (MA(I,10) - MR(M))43,41,42
   41 IR(I) = M
      GO TO 44
   42 CONTINUE
   43 PRINT 45,MA(I,2),MA(I,4)
      IM(I) = 99
      GO TO 72
   44 CONTINUE
   72 CONTINUE
C
      PRINT 53,IRUN
      PRINT 400
      PRINT 401,((I,(MA(I,J),J=1,6),MA(I,8),MA(I,9),(MA(I,J),J=12,15)),
     1I=1,N)
      PRINT 402,((I,A(I)),I=1,12)
      PRINT 403
      PRINT 404, (J,(KS(I,J) ,I=1,8),J=1,NSHIP)
      PRINT 54
      PRINT 52
      PRINT 51,(((SA(I,J),I=1,15),ID(J),(SA(I,J),I=16,30),IP(J)),J=1,NSH
     1IP)
      JA = 1  $  JB = NSHIP
      DO 90 I2=1,N
C
C  EXECUTE THIS LOOP FOR ASSIGNMENT
C
      DO 88 I=1,N
```

```
      GR(I)=0.
      IF(IM(I))84,84,88
   84 DO 189 J=JA,JB
      CALL RATIO(IR(I),I,J)
      U(I,J)=A(1)
      DO 189 K=1,11
      U(I,J)=U(I,J)+W(I,J,K)*A(K+1)
  189 CONTINUE
   88 CONTINUE
      CALL ASSIGN(N,IR,IM,LM)
      IK(LM)=I2
      JA=IM(LM)
      JB=IM(LM)
   90 CONTINUE
C
      PRINT 55
      PRINT 52
      PRINT 51,(((SA(I,J),I=1,15),ID(J),(SA(I,J),I=16,30),IP(J)),J=1,NSH
     1IP)
  999 CONTINUE
    2 FORMAT(6A8,13X,A5,A1,I1,4X,I5/11X,I1,11X,A1,I1,14X,2A1)
   10 FORMAT(2A8,4X,2(A1,I1,8X),A1,4X,I2)
   11 FORMAT (15F4.0,8X,A8)
   45 FORMAT (20H ERROR IN RATE CODE ,2A8)
   49 FORMAT(2I10)
   51 FORMAT(3(5F4.0, 5X),A8,/,3(5F4.0, 5X),A8,/,/)
   52 FORMAT   (40X7HEDP/POB,/,/,10X2HBM23X2HQM23X2HSM,/,/)
   53 FORMAT(1H130X27H** BEGIN RUN FROM DATA SET I2,3H **,/,/)
   54 FORMAT(1H1,32X,19H(BEFORE ASSIGNMENT))
   55 FORMAT(1H1,32X,19H(AFTER  ASSIGNMENT))
  400 FORMAT(1H0/30X18HMEN TO BE ASSIGNED,/,/)
  401 FORMAT(1H I2,3X,6A8,3X,3HTU ,A1,I1,3X5HEAOS ,A1,I1,3X3HHP ,2A1)
  402 FORMAT(1H0/20X27H WEIGHTS USED IN ASSIGNMENT/12(/27X3H A(
     1I2,2H)=F6.3))
  403 FORMAT(1H0/20X23HSHIPS TO BE ASSIGNED TO/ )
```

```
404 FORMAT(5X,I2,5X,2A8,4X,2(A1,I1,8X),A1,I8)
881 FORMAT(12F5.2)
    END
```

APPENDIX D

Part 2

Function Subprogram IDA

Subroutine Subprogram RATIO

Subprogram Subroutine ASSIGN

APPENDIX D

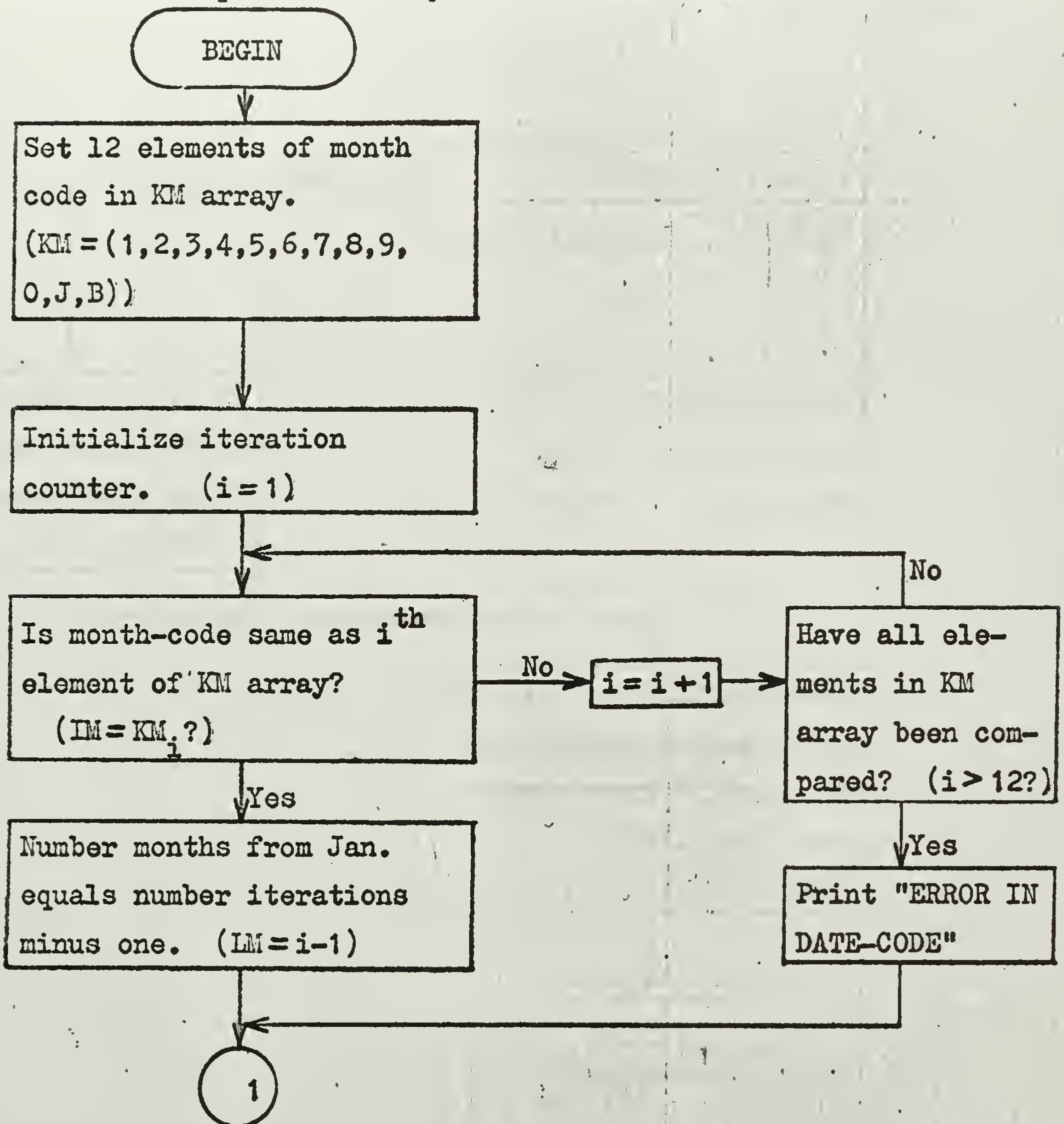
TABLE OF VARIABLES AND CONSTANTS USED IN FUNCTION IDA

1.	IM	Alpha-numeric month code.
2.	IY	Numeric year code.
3.	KM(I)	Table of month codes for decoding IM.
4.	LM	No. of months from January.
5.	LY	No. of years from 1965.
6.	IDA	No. of months from January 1965.

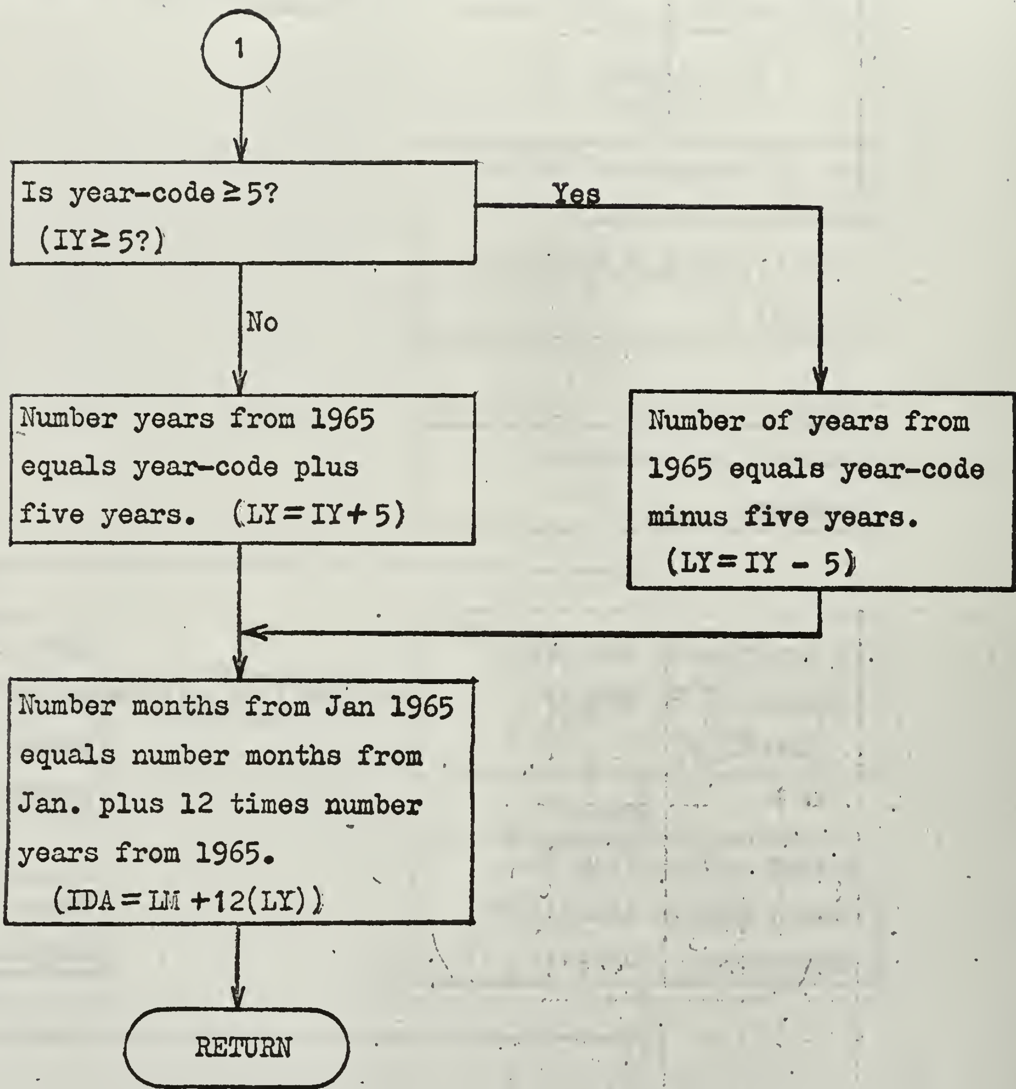
APPENDIX D

Plain-language Flow-Chart for Function Subprogram IDA

FUNCTION IDA converts month-year code (IM,IY) to number of months from January 1965. All date codes are assumed to be included in period January 1965-December 1974.



APPENDIX D


1
Is year-code ≥ 5?
(IY ≥ 5?)
Yes
No
Number years from 1965 equals year-code plus five years. (LY = IY + 5)
Number of years from 1965 equals year-code minus five years. (LY = IY - 5)
Number months from Jan 1965 equals number months from Jan. plus 12 times number years from 1965. (IDA = LM + 12(LY))
RETURN

```
      FUNCTION IDA(IM,IY)
C
C  THIS SUBPROGRAM CONVERTS MO-YR CODE TO NO. OF MONTHS FROM JAN 65
C
      DIMENSION KM(12)
      DATA(KM=1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1HJ,1HB)
      DO 1 I=1,12
      IF(IM.EQ. KM(I))2,1
    2 LM=I-1
      GO TO 3
    1 CONTINUE
      PRINT 9,IM,IY
    3 IF(IY-5)4,5,5
    4 LY=IY+5
      GO TO 6
    5 LY=IY-5
    6 IDA=LM+12*LY
    9 FORMAT(18H IDA ERROR IM,IY= A1,I1)
      RETURN
      END
```

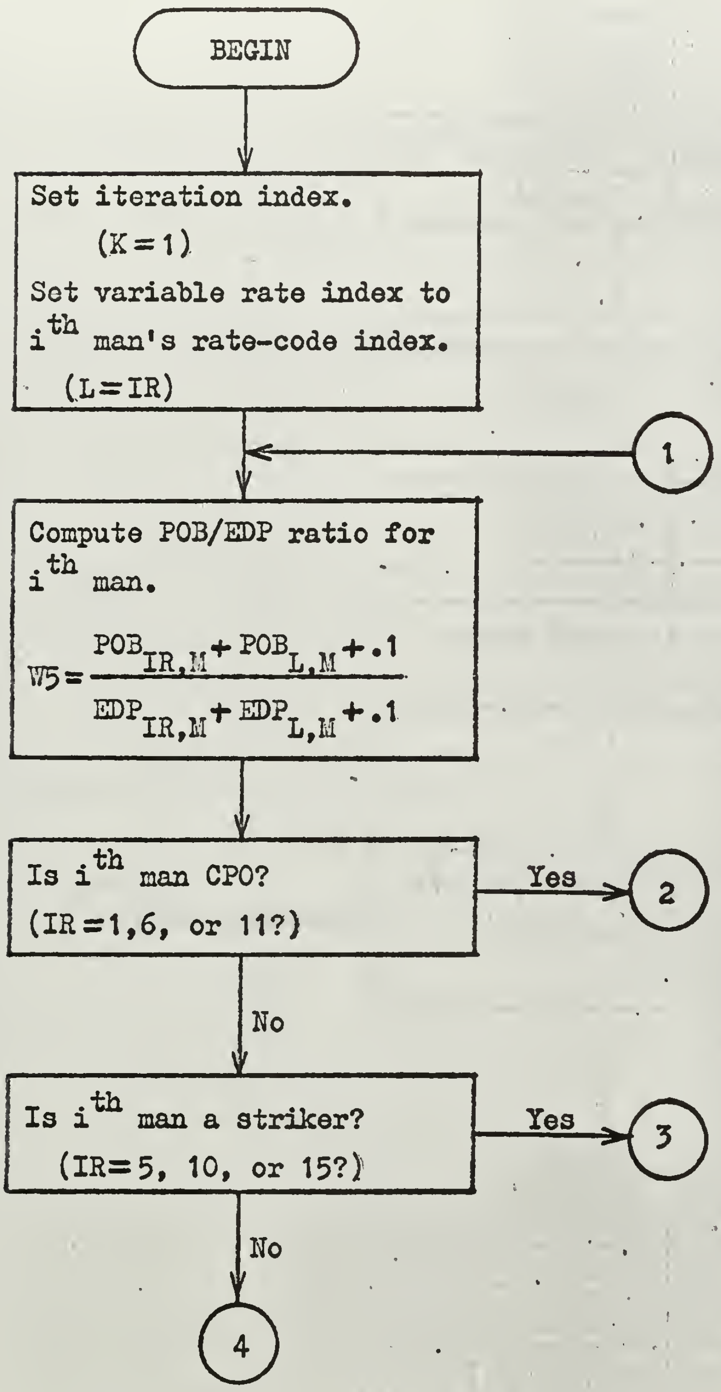
APPENDIX D

TABLE OF VARIABLES AND CONSTANTS USED IN SUBROUTINE RATIO

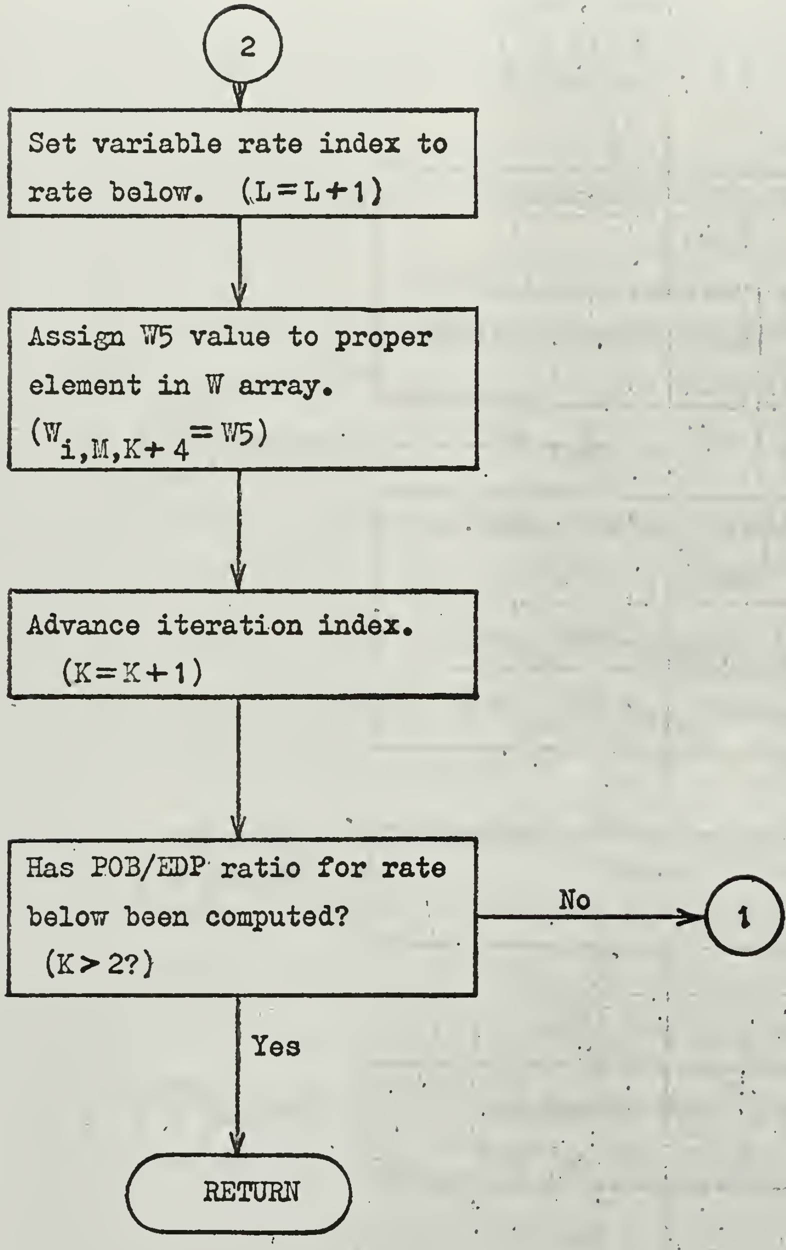
1.	S(L,M)	EDP-POB values for ship M. Same as SA(L,M).
2.	XE	EDP for rate or rate above or rate below that of I^{th} man on M^{th} ship.
3.	XEE	EDP for rate of I^{th} man on M^{th} ship + .1.
4.	XP	POB for rate or rate above or rate below that of I^{th} man on M^{th} ship.
5.	XPP	POB + .1 for rate of I^{th} man on M^{th} ship.
6.	W5	Dummy variable for temporary storage of (POB)/(EDP) ratio.
7.	L	Subscript corresponding to rate code index for I^{th} man. Varies to include rate above and/or below values.
8.	K	Iteration counter used to place W5 value in proper element of W_{ijk} array and to terminate ratio process.

APPENDIX D

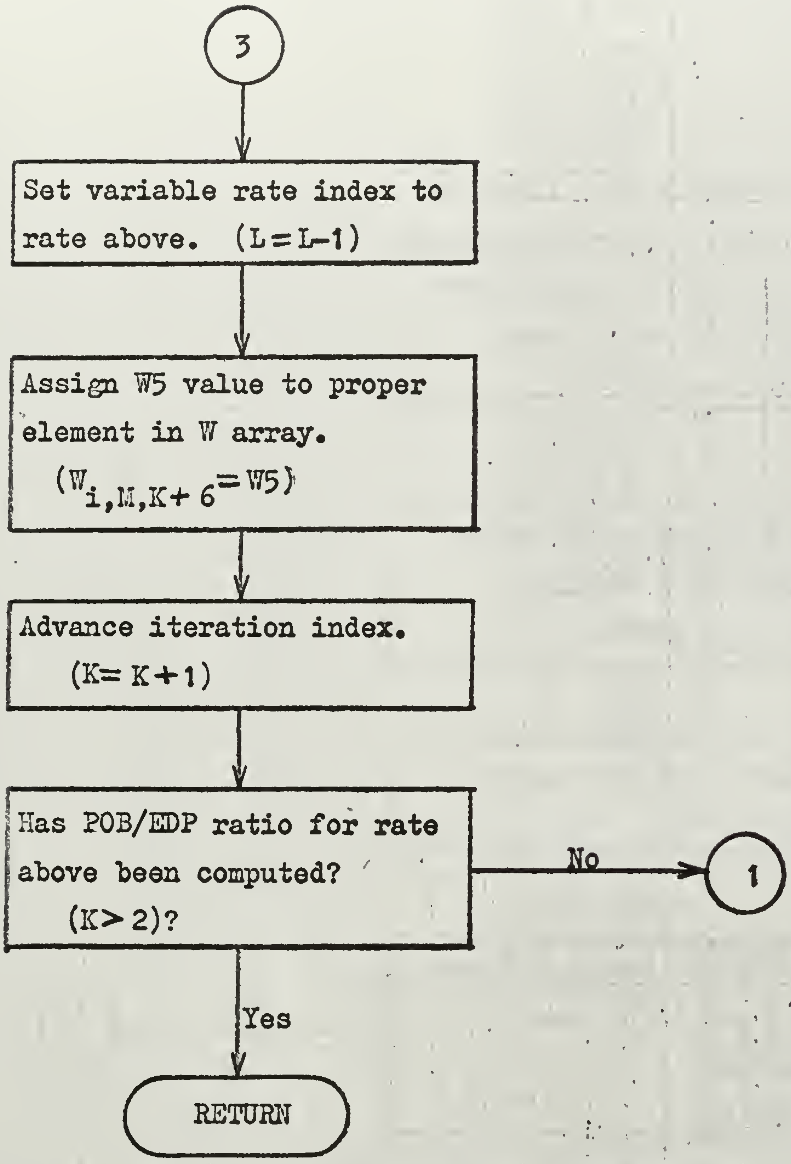
Plain-language Flow-chart for Subroutine Subprogram RATIO



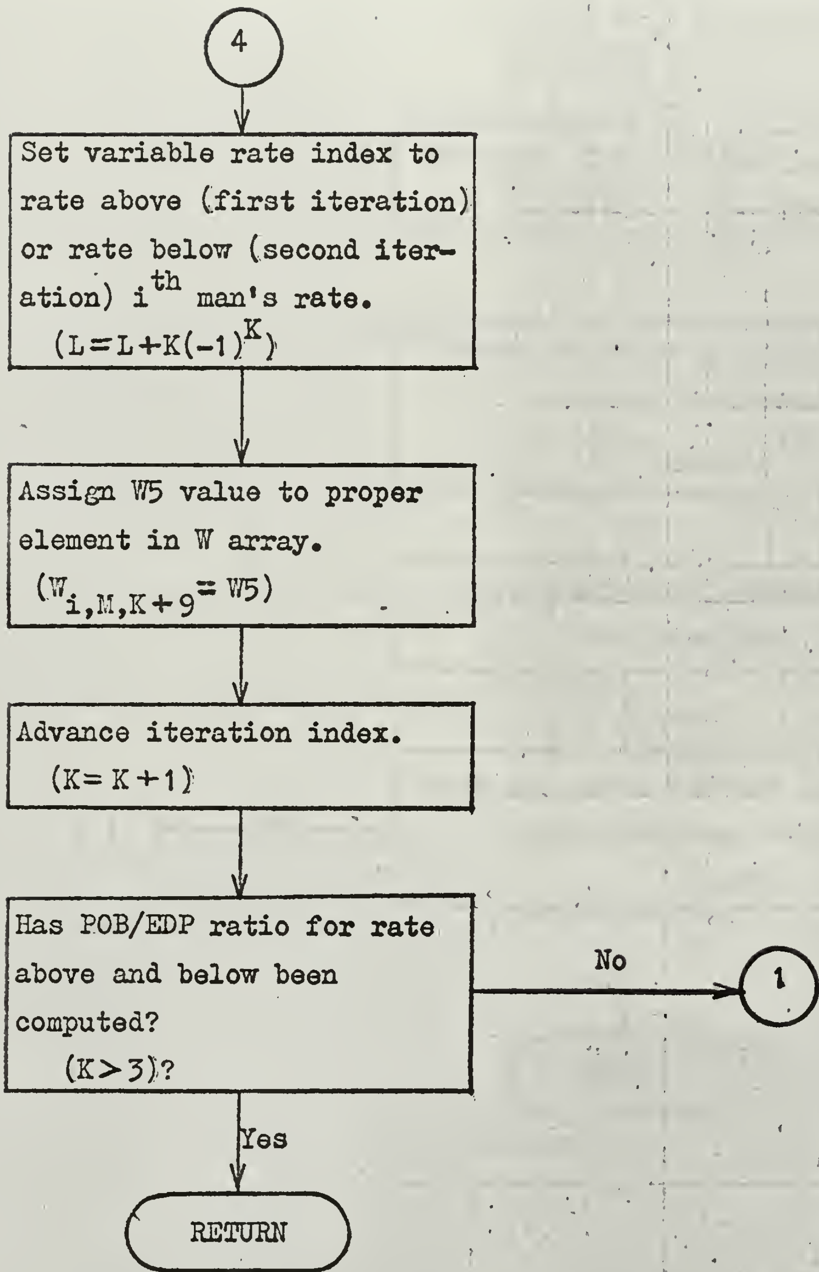
APPENDIX D


2
Set variable rate index to rate below. (L=L+1)
Assign W5 value to proper element in W array. ($W_{i,M,K+4}$ = W5)
Advance iteration index. (K=K+1)
Has POB/EDP ratio for rate below been computed? (K > 2?)
No
1
Yes
RETURN

APPENDIX D


3
Set variable rate index to rate above. (L=L-1)
Assign W5 value to proper element in W array. ($W_{i,M,K+6}$=W5)
Advance iteration index. (K=K+1)
Has POB/EDP ratio for rate above been computed? (K>2)?
No
1
Yes
RETURN

APPENDIX D


4
Set variable rate index to rate above (first iteration) or rate below (second iteration) i^{th} man's rate.
$(L = L + K(-1)^K)$
Assign W5 value to proper element in W array.
$(W_{i,M,K+9} = W5)$
Advance iteration index.
$(K = K + 1)$
Has POB/EDP ratio for rate above and below been computed?
$(K > 3)$?
No
1
Yes
RETURN

```
      SUBROUTINE RATIO(IR,I,M)
C
C  FOR MANS RATE, COMPUTE POB/EDP RATIO FOR ALL SHIPS.
C  THEN DO SAME FOR RATE ABOVE AND/OR BELOW.
C
      COMMON   S,W,MA,KS,U,NSHIP
      DIMENSION S(30,16),W(50,16,15),MA(50,15),KS(8,16),U(50,16)
      K=1 $          L=IR
    8 XE=S(L,M) $ XP= S(L+15,M)
      XEE=S(IR,M)+.1 $   XPP=S(IR+15,M)+.1
      W5  =(XP+XPP)/(XE+XEE)
C
   21 GO TO (5,6,6,6,7,5,6,6,6,7,5,6,6,6,7)IR
C
    5 L=L+1 $ W(I,M,K+4)= W5 $ K=K+1
      IF(K-2)8,8,9
C  HAS COMPUTED CPO,NOW COMPUTES PO1
C
    6 L=L+K*(-1)**K$ W(I,M,K+6)=W5 $ K=K+1
      IF(K-3)8,8,9
C  HAS COMPUTED PO1 OR PO2 OR PO3, NOW COMPUTE RATE ABOVE AND BELOW
C
    7 L=L-1 $ W(I,M,K+9)=W5$ K=K+1
      IF(K-2)8,8,9
C  HAS COMPUTED SN, NOW COMPUTE PO3
C
    9 CONTINUE
      RETURN
      END
```

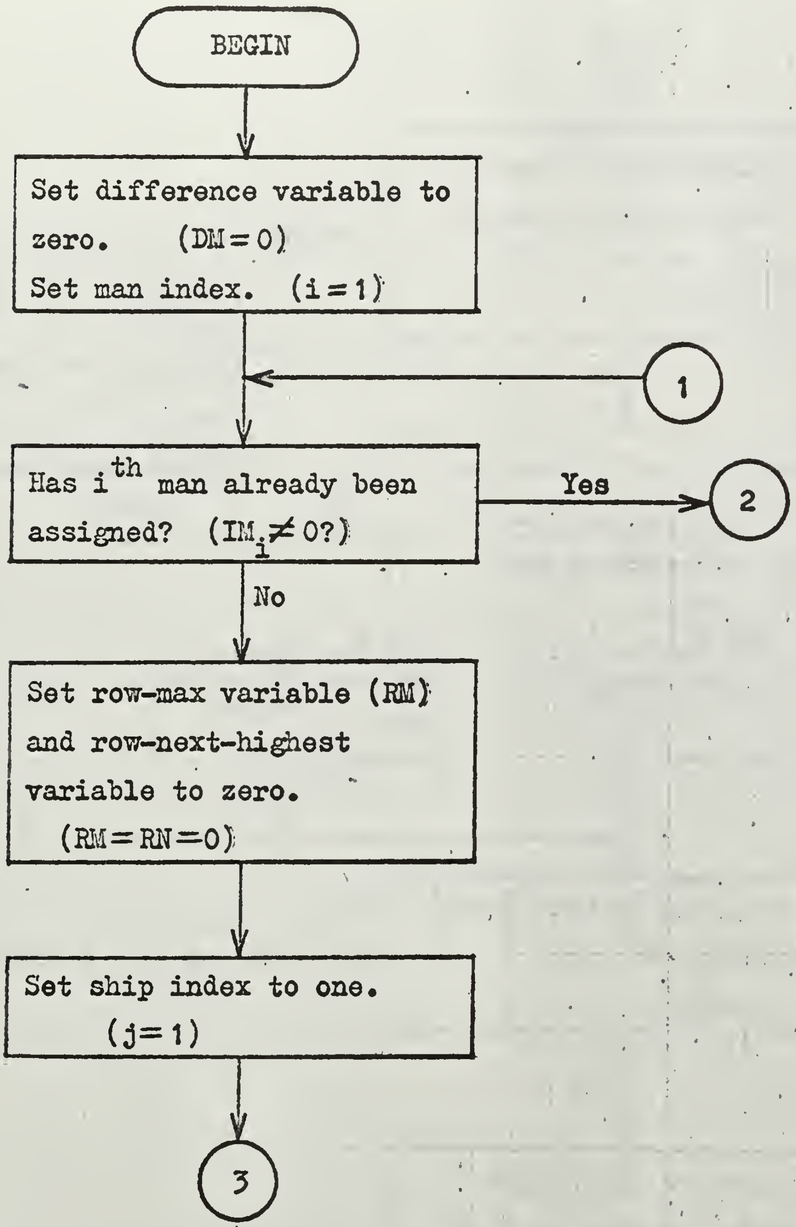
APPENDIX D

TABLE OF VARIABLES AND CONSTANTS USED IN SUBROUTINE ASSIGN

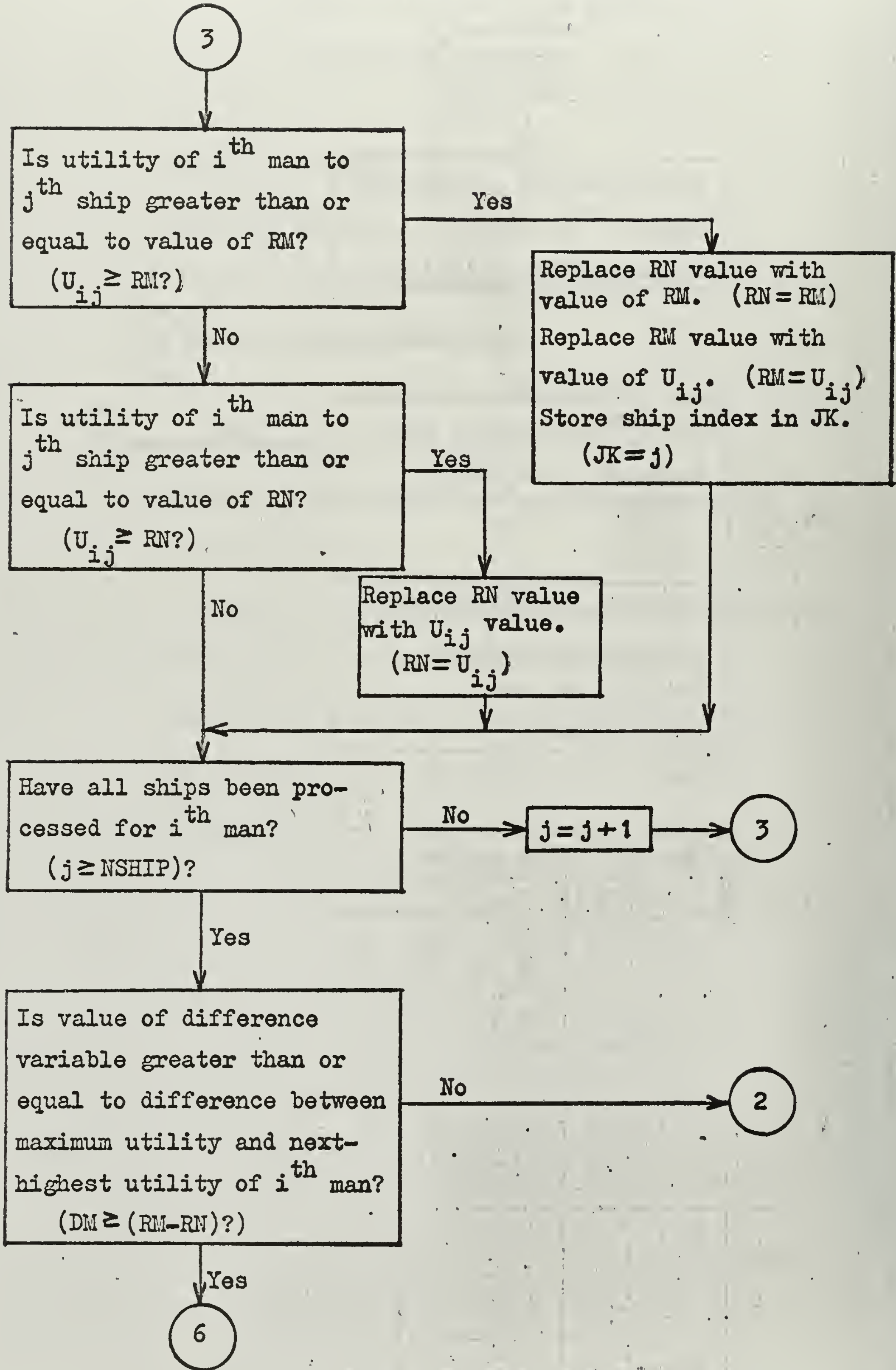
1.	RM	Maximum utility of I^{th} man.
2.	RN	Next highest utility of I^{th} man.
3.	DM	Maximum difference between RM and RN for all unassigned men.
4.	JK	Temporary storage for number of ship which has highest utility for I^{th} man.
5.	LM	Number of man (utility array row) which is to be assigned.
6.	JS	Number of ship (utility array column) to which LM^{th} man is to be assigned.
7.	IT	Dummy variable which defines column in POB array to be corrected when man is assigned.

APPENDIX D

Plain-language Flow-chart for Subprogram Subroutine ASSIGN

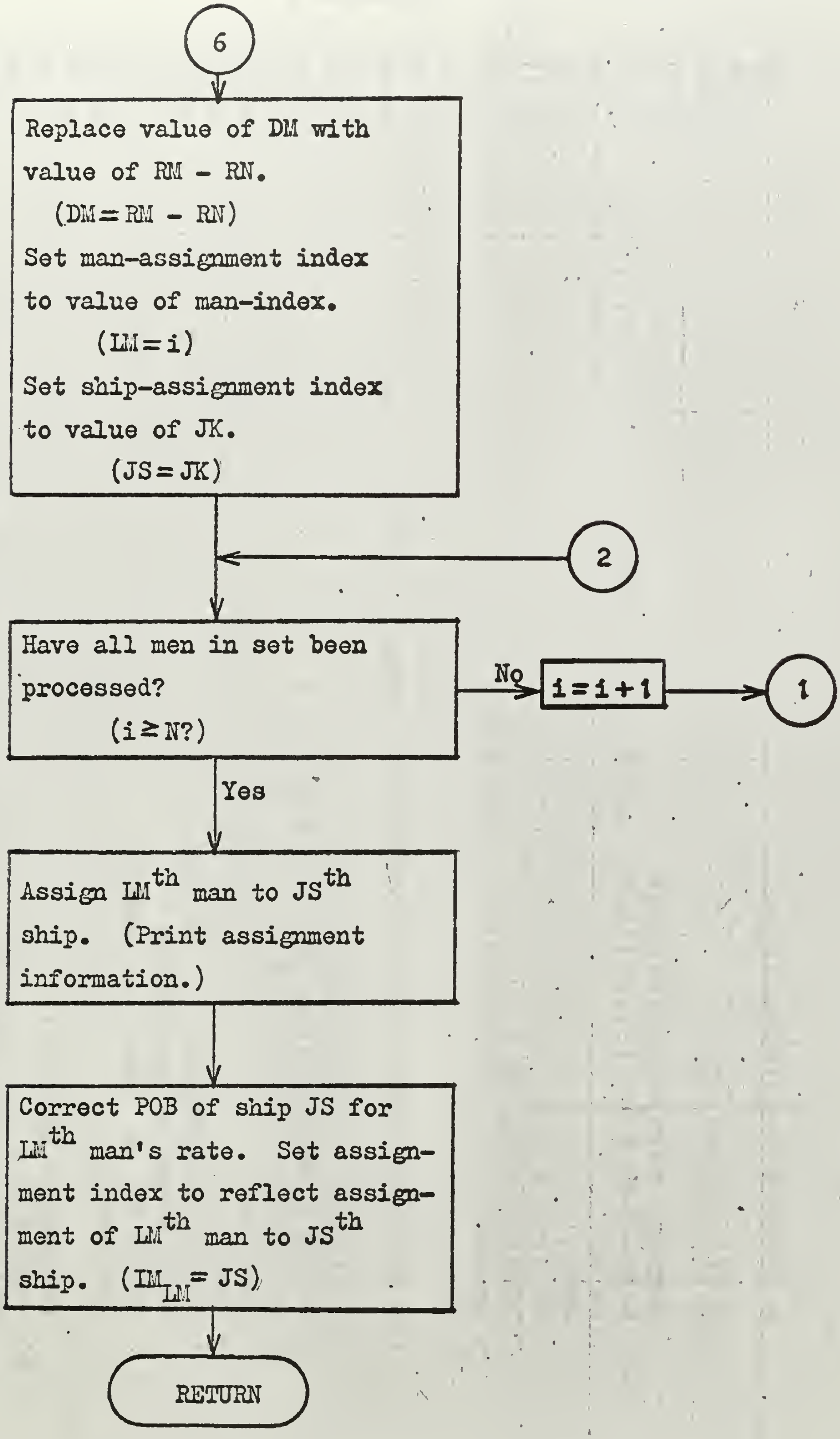


APPENDIX D



3
Is utility of i^{th} man to j^{th} ship greater than or equal to value of RM? ($U_{ij} \geq RM$?)
Yes
Replace RN value with value of RM. (RN = RM)
Replace RM value with value of U_{ij}. ($RM = U_{ij}$)
Store ship index in JK. (JK = j)
No
Is utility of i^{th} man to j^{th} ship greater than or equal to value of RN? ($U_{ij} \geq RN$?)
Yes
Replace RN value with U_{ij} value. ($RN = U_{ij}$)
No
Have all ships been processed for i^{th} man? ($j \geq NSHIP$)?
No
$j = j + 1$
3
Yes
Is value of difference variable greater than or equal to difference between maximum utility and next-highest utility of i^{th} man? ($DM \geq (RM-RN)$?)
No
2
Yes
6

APPENDIX D


6
Replace value of DM with value of RM - RN.
(DM = RM - RN)
Set man-assignment index to value of man-index.
(LM = i)
Set ship-assignment index to value of JK.
(JS = JK)
2
Have all men in set been processed?
(i ≥ N?)
No
i = i + 1
1
Yes
Assign LM^th man to JS^th ship. (Print assignment information.)
Correct POB of ship JS for LM^th man's rate. Set assignment index to reflect assignment of LM^th man to JS^th ship. (IM_LM = JS)
RETURN

APPENDIX D

```
      SUBROUTINE ASSIGN(N,IR,IM,LM)
C
C   MODIFIED VAM METHOD
C
      COMMON  SA,W,MA,KS,U,NSHIP
      DIMENSION KS(8,16),SA(30,16),W(50,16,15),MA(50,15),U(50,16),IR(N),
     1IM(N)
      DM=0.
      DO 72 I = 1,N
      IF(IM(I))5,5,72
    5 RM=RN=0.
      DO 3 J=1,NSHIP
C
C   FIND MAX U IN EACH ROW AND DIFFERENCE BETWEEN SECOND HIGHEST U
C
      IF(U(I,J) -  RM)6,2,2
    2 RN=RM $ RM=U(I,J) $ JK    =J $ GO TO 3
    6 IF(U(I,J) -  RN)3,4,4
    4 RN=U(I,J)
    3 CONTINUE
C   FIND MAX DIFFERENCE
      IF((RM-RN) -  DM)72,8,8
    8 DM=RM-RN  $  LM=I  $  JS=JK
   72 CONTINUE
C
      IF(IM(LM))31,30,31
   30 CONTINUE
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)
```

```
      IM(LM)=JS
      IT=IR(LM)+15
C
C   UPDATE POB-6
C
      SA(IT,JS)=SA(IT,JS)+1.
      PRINT 111,MA(LM,2),MA(LM,4)
      DO 16 J = 1,NSHIP
   16 PRINT 15,LM,J,(W(LM,J,K),K=1,11),U(LM,J)
   14 FORMAT(1H0,5X8H ASSIGN ,A8,1X,A4,4H TO ,2A8, 5X,2I4,F10.3)
   15 FORMAT(2I3,4F5.0,7F6.2,F9.2)
  111 FORMAT(1H0,5X,25H W VECTOR AND UTILITY OF ,A8,1X,A4,
     114H FOR ALL SHIPS)
   31 CONTINUE
      RETURN
      END
```

APPENDIX D

Modification to Program AUTAM* for Row-Column Method of Assignment

```
      JA = 1
      DO 90 I2=1,N
C
C  EXECUTE THIS LOOP FOR ASSIGNMENT
C
      DO 88 I=1,N
      GR(I)=0.
      IF(IM(I))86,86,88
   86 DO 189 J=1,NSHIP
      CALL RATIO(IR(I),I,J)
      U(I,J)=A(1)
      DO 189 K=1,11
      U(I,J)=U(I,J)+W(I,J,K)*A(K+1)
  189 CONTINUE
   88 CONTINUE
      CALL ASSIGN(N,IR,IM,JA,IK)
```

*Statements shown above replace card numbers 0100-0115 (inclusive) in Program AUTAM.

APPENDIX D

Modification to Program AUTAM* for Marginal Utility Computation

```
      SU=SRU=TN=0.
      DO 168 I=1,N
      IF(IM(I)-99)171,168,168
  171 J = IM(I)
      IRA=IR(I)+15
      SA(IRA,J)=SA(IRA,J)-1.
      CALL RATIO(IR(I),I,J)
      T=A(1)
      DO 188 K=1,11
      GR(K)=GR(K)+W(I,J,K)
  188 T=T+W(I,J,K)*A(K+1)
      SU=SU+U(I,J)
      SRU=SRU+T
      SA(IRA,J)=SA(IRA,J)+1.
      PRINT 170,I,J,U(I,J),T,IK(I),(W(I,J,K),K=1,11)
      TN=TN+1.
  168 CONTINUE
      PRINT 172,SU,SRU,(GR(K),K=1,11)
      SU=SU/TN    $   SRU=SRU/TN
      DO 173 K=1,11
  173 GR(K)=GR(K)/TN
      PRINT 172,SU,SRU,(GR(K),K=1,11)
  170 FORMAT(1H ,2I5,2F10.3,5X,I3,2X,11F7.2)
  172 FORMAT(11X,2F10.3,10X,11F7.3)
```

*The above statements follow card number 0124 in Program AUTAM.

APPENDIX E

1. Program Listing for Row-Max Method

```
      SUBROUTINE ASSIGN(N,IR,IM,LM)
C   ASSIGN TO MAX UTILITY IN EACH ROW SEQUENTIALLY
C
      COMMON  SA,W,MA,KS,U,NSHIP
      DIMENSION KS(8,16),SA(30,16),W(50,16,15),MA(50,15),U(50,16),IR(N),
     1IM(N),UM(50),DIFM(50),JK(50)
      UMAX = -10.
      DO 74  I = 1,N
      IF(IM(I))5,5,74
    5 DO 72  J = 1,NSHIP
      IF(UMAX-U(I,J))73,73,72
   73 UMAX = U(I,J)
      LM=I   $   JS = J
   72 CONTINUE
      GO TO 7
   74 CONTINUE
    7 CONTINUE
      IF(IM(LM))31,30,31
   30 CONTINUE
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)
      IM(LM)=JS
      IT=IR(LM)+15
C
C   UPDATE PCB-6
C
      SA(IT,JS)=SA(IT,JS)+1.
      PRINT 111,MA(LM,2),MA(LM,4)
      DO 16  J = 1,NSHIP
   16 PRINT 15,LM,J,(W(LM,J,K),K=1,11),U(LM,J)
   14 FORMAT(1H0,5X8H ASSIGN ,A8,1X,A4,4H TO ,2A8, 5X,2I4,F10.3)
   15 FORMAT(2I3,4F5.0,7F6.2,F9.2)
  111 FORMAT(1H0,5X,25H W VECTOR AND UTILITY OF ,A8,1X,A4,
     114H FOR ALL SHIPS)
   31 CONTINUE
      RETURN
      END
```

APPENDIX E

2. Program Listing for Array-Max Method

```
      SUBROUTINE ASSIGN(N,IR,IM,LM)
C   ARRAY MAX METHOD                                                   0237
      COMMON  SA,W,MA,KS,U,NSHIP                                       0239
      DIMENSION KS(8,16),SA(30,16),W(50,15,15),MA(50,15),U(50,16),IR(N),  0240
     1IM(N),UM(50),DIFM(50),JK(50)                                     0241
      UMAX = -10.                                                      0242
      DO 74 I = 1,N                                                    0243
      IF(IM(I))5,5,74                                                  0244
    5 DO 72 J = 1,NSHIP                                                0245
      IF(UMAX-U(I,J))73,73,72                                          0246
   73 UMAX = U(I,J)                                                    0247
      LM=I   $   JS = J                                                0248
   72 CONTINUE                                                         0249
   74 CONTINUE                                                         0250
      IF(IM(LM))31,30,31                                               0254
   30 CONTINUE
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)     0263
      IM(LM)=JS                                                        0269
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)     0220
      IM(LM)=JS                                                        0221
      IT=IR(LM)+15                                                     0222
C                                                                      0223
C   UPDATE PCB-6                                                       0224
C                                                                      0225
      SA(IT,JS)=SA(IT,JS)+1.                                           0226
      PRINT 111,MA(LM,2),MA(LM,4)                                      0227
      DO 16 J = 1,NSHIP                                                0228
   16 PRINT 15,LM,J,(W(LM,J,K),K=1,11),U(LM,J)                         0229
   14 FORMAT(1H0,5X8H ASSIGN ,A8,1X,A4,4H TO ,2A8, 5X,2I4,F10.3)       0230
   15 FORMAT(2I3,4F5.0,7F6.2,F9.2)                                     0231
  111 FORMAT(1H0,5X,25H W VECTOR AND UTILITY OF ,A8,1X,A4,             0232
     114H FOR ALL SHIPS)                                               0233
   31 CONTINUE                                                         0234
      RETURN                                                           0235
      END                                                              0236
```

3. Program Listing for Row-Column-Max Method

```
      SUBROUTINE ASSIGN(N,IR,IM,JA,IK)                                            0445
C   ROW-COLUMN MAX METHOD                                                         0446
      COMMON  SA,W,MA,KS,U,NSHIP                                                  0449
      DIMENSION KS(8,16),SA(30,16),W(50,16,15),MA(50,15),U(50,16),IR(N),          0450
     1IM(N),IK(50)                                                                0451
      DO 72 L=1,NSHIP                                                             0452
      UMAX = -10.                                                                 0453
      DO 74 I=1,N                                                                 0454
      IF(IM(I))5,5,74                                                             0455
    5 IF(UMAX - U(I,L))73,74,74                                                   0456
   73 UMAX = U(I,L)                                                               0457
      LM = I  $  JS = L                                                           0458
   74 CONTINUE                                                                    0459
      DO 75 M = 1,NSHIP                                                           0460
      IF(UMAX - U(LM,M))72,75,75                                                  0461
   75 CONTINUE                                                                    0462
      IF(IM(LM))31,30,31                                                          0466
   30 CONTINUE
      IM(LM)=JS  $  IK(LM) = JA  $  JA=JA+1                                       0481
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)                0220
      IT=IR(LM)+15                                                                0222
C                                                                                 0223
C   UPDATE POB-6                                                                  0224
C                                                                                 0225
      SA(IT,JS)=SA(IT,JS)+1.                                                      0226
      PRINT 111,MA(LM,2),MA(LM,4)                                                 0227
      DO 16 J = 1,NSHIP                                                           0228
   16 PRINT 15,LM,J,(W(LM,J,K),K=1,11),U(LM,J)                                    0229
   14 FORMAT(1H0,5X8H ASSIGN ,A8,1X,A4,4H TO ,2A8, 5X,2I4,F10.3)                  0230
   15 FORMAT(2I3,4F5.0,7F6.2,F9.2)                                                0231
  111 FORMAT(1H0,5X,25H W VECTOR AND UTILITY OF ,A8,1X,A4,                        0232
     114H FOR ALL SHIPS)                                                          0233
   31 CONTINUE                                                                    0234
      RETURN                                                                      0235
      END                                                                         0236
```

4. Program Listing for Decision-Index Method

```
      SUBROUTINE ASSIGN(N,IR,IM,LM)
C
C  DECISION INDEX METHOD
C
      COMMCN  SA,W,MA,KS,U,NSHIP
      DIMENSION KS(8,16),SA(30,16),W(50,15,15),MA(50,15),U(50,16),IR(N),
     1IM(N),UM(50),DIFM(50),JK(50)
      DIMENSIJN D(50,16), CR(50), CC(16)
      TN=0.
      DO 3 I=1,N
      IF(IM(I))5,5,3
    5 CR(I)=0.
      TN=TN+1.
      DO 2 J=1,NSHIP
    2 CR(I)=CR(I)+U(I,J)
    3 CONTINUE
      DO 4 J=1,NSHIP
      CC(J)=0.
      DO 4 I=1,N
      IF(IM(I))6,6,4
    6 CC(J)=CC(J)+U(I,J)
    4 CONTINUE
      DM=-10000.
      DO 7 I=1,N
      IF(IM(I))9,9,7
    9 DO 7 J=1,NSHIP
      IF(TN.EQ.1.)12,11
   11 D(I,J)=TN*U(I,J)-CR(I)-CC(J)
      GO TO 10
   12 D(I,J)=U(I,J)
   10 IF(D(I,J)-DM)7,7,8
    8 DM=D(I,J) $ JS=J $ LM=I
    7 CONTINUE
      IF(IM(LM))31,30,31
```

```
   30 CONTINUE
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)          0263
      IM(LM)=JS                                                              0269
      PRINT 14,MA(LM,2),MA(LM,4),KS(1,JS),KS(2,JS),LM,JS, U(LM,JS)          0220
      IM(LM)=JS                                                              0221
      IT=IR(LM)+15                                                           0222
C                                                                            0223
C  UPDATE POB-6                                                              0224
C                                                                            0225
      SA(IT,JS)=SA(IT,JS)+1.                                                 0226
      PRINT 111,MA(LM,2),MA(LM,4)                                            0227
      DO 16 J = 1,NSHIP                                                      0228
   16 PRINT 15,LM,J,(W(LM,J,K),K=1,11),U(LM,J)                               0229
   14 FORMAT(1H0,5X8H ASSIGN ,A8,1X,A4,4H TO ,2A8, 5X,2I4,F10.3)             0230
   15 FORMAT(2I3,4F5.0,7F6.2,F9.2)                                           0231
  111 FORMAT(1H0,5X,25H W VECTOR AND UTILITY OF ,A8,1X,A4,                   0232
     114H FOR ALL SHIPS)                                                     0233
   31 CONTINUE                                                               0234
      RETURN                                                                 0235
      END                                                                    0236
```

** BEGIN RUN FROM DATA SET 1 **

MEN TO BE ASSIGNED

1	7184408	MCCRE KENN	BM1	MCBASE CP LEJUN C33	TU	36	EAOS	88	HP	PI
2	4518802	MAY CHARLES D	SM2	NAVSTA SDIEGO OTH	TU	J5	EACS	07	HP	YX
3	3746803	TAYLOR W C	SM2	NAVSTA LBEACH C72	TU	J5	EACS	09	HP	XV
4	9954205	NAKAMOTO W	BM1	COMMSTA SFRISCO C76	TU	36	EACS	68	HP	ZW
5	5400813	THOMPSCN K H	BM3	NAVSTA SFRAN	TU	05	EAOS	J9	HP	Y
6	5208925	ANDERSCN W	BM3	USNH CP LEJUN NCC31	TU	36	EACS	87	HP	NW
7	5214922	HADLEY MEL	BM3	USNH SAN DIEGO C71	TU	36	EAOS	38	HP	YW
8	6865925	GIFFORC D J	QM3	TAP114 GEN WM MITCH	TU	85	EAOS	17	HP	
9	4198530	SPENCER W F	BMSN	NAVSTA NCRVA C32	TU	J5	EAOS	80	HP	CD
10	7496933	DUDLEY CCNALD E	SM2	NS LBEACH OTH	TU	05	EACS	87	HP	VV
11	4843735	VEGA CHARL	QM1	LSD 27 WHETSTONP40	TU	46	EAOS	57	HP	22
12	6529242	BARAN ECWA	BMC	NAS QUONSE PT 311	TU	16	EAOS	67	HP	UY
13	5659541	VILLASENOR	BM1	OTS PAS ANN LBCHC73	TU	26	EAOS	77	HP	Y
14	5717256	DOWNS H P	QM2	TAP114 GEN WM MITCH	TU	85	EAOS	17	HP	
15	8735557	ENGLANC I L JR	BM3	NAVSTA ADAK	TU	46	EAOS	08	HP	
16	5879454	BRCWN W G	BMSN	TAP114 GEN WM MITCH	TU	85	EAOS	J9	HP	
17	5941052	DUNHAM KENNETH E	SM3	NS LBEACH OTH	TU	05	EACS	56	HP	XW
18	6005167	STUART FRA	BM3	NAF ANDREWS AFB C85	TU	36	EACS	97	HP	CF
19	3118164	ABRAMCWICZ	BMC	NS NEWPORT RI C14	TU	36	EAOS	07	HP	EE
20	8195268	PUGH CHARL	BM3	NS WASHINGTCN CCC88	TU	26	EAOS	78	HP	
21	5440169	WHITTAKER J R	BMSN	NAVSTA KCDIAK	TU	46	EACS	27	HP	YZ
22	2815768	GREGORY FR	BM2	CRD UN KEY WEST C45	TU	85	EACS	88	HP	PL
23	5201274	GARRICC IG	QM1	CER 322 NEWELL P64	TU	46	EAOS	78	HP	11
24	9738474	JAMES GECR	SM3	NAAS REAMFLD CALC70	TU	36	EAOS	87	HP	XY
25	5119084	TRICE ROBE	SM3	NAVFAC LEWES DELL00	TU	85	EACS	67	HP	WX
26	3483284	HUGHES WIL	BM2	TRARCN 31 C96	TU	36	EACS	27	HP	SW
27	5676585	KERSCN J E JR	BM1	NAVHOSP BREM	TU	05	EACS	16	HP	VV
28	4583793	WENGER ROB	BM2	COMMSTOR HUENEMEC71	TU	36	EACS	79	HP	XW
29	3613592	MINGUS ELM	BM1	ATF 110 QUAPAW P14	TU	46	EACS	19	HP	11
30	9654993	OLINGER KE	BM2	U/W CRDSTA NEWPTC13	TU	36	EACS	30	HP	RT

APPENDIX F

WEIGHTS USEC IN ASSIGNMENT

```
A( 1)=10.000
A( 2)=   .260
A( 3)=  -.300
A( 4)=  1.410
A( 5)=   .330
A( 6)=-3.500
A( 7)=-1.590
A( 8)=-2.270
A( 9)=-1.940
A(10)=  -.880
A(11)=-3.140
A(12)=-1.820
```

SHIPS TO BE ASSIGNED TO

1	USS GCLF	05	66	Y	7
2	USS KILC	85	36	X	11
3	USS ECHC	96	47	W	5
4	USS CSCAR	85	66	Y	15
5	USS LIMA	J6	67	X	12
6	USS JULIET	16	76	X	10
7	USS HCTEL	56	37	Y	8
8	USS FOXTRCT	B5	96	W	6
9	USS DELTA	45	B5	Y	4
10	USS BRAVC	J5	86	W	2

(BEFORE ASSIGNMENT)
EDP/POB

BM					CM					SM					
2 1	6 5	18 15	32 25	1 1	0 0	1 0	1 3	4 4	1 1	1 1	1 1	2 5	8 4	2 0	E 7 1P 7
1 0	4 6	8 4	16 9	0 1	0 0	1 1	1 0	3 4	0 1	1 1	1 1	1 1	4 6	3 2	E11 1P11
2 2	6 6	15 13	19 14	0 2	0 0	1 1	1 1	4 8	1 0	1 1	1 1	1 4	6 6	1 0	E 5 1P 5
1 1	2 1	4 3	6 6	0 2	0 0	1 0	0 0	1 0	0 2	0 0	1 1	1 1	1 1	0 0	E15 1P15
1 1	4 4	8 11	16 12	0 0	0 0	1 1	1 1	3 4	0 0	1 1	1 1	1 3	4 5	3 0	E12 1P12
1 1	4 3	8 9	16 10	0 1	0 0	1 0	1 3	3 3	0 2	1 1	1 1	1 2	4 5	3 2	E10 1P10
2 1	6 8	18 22	32 24	1 3	0 0	1 2	1 1	4 3	1 3	1 0	1 2	2 3	8 5	2 0	E 8 1P 8
2 1	6 6	19 18	31 18	1 9	0 1	1 0	1 2	4 3	1 5	1 0	1 0	2 3	8 6	2 1	E 6 1P 6
1 3	5 2	8 6	13 8	1 0	0 1	1 0	1 1	3 4	0 0	0 1	1 1	2 3	4 4	2 1	E 4 1P 4
1 0	5 4	8 9	13 14	1 0	0 0	1 1	1 0	3 6	0 1	0 0	2 1	1 3	4 7	3 0	E 2 1P 2

ASSIGN KERSCN J BM1 TO USS DELTA 27 9 8.022

W VECTOR AND UTILITY OF KERSON J BM1 FOR ALL SHIPS

27	1	0	0	0	0	0	0	.83	.75	.83	0	0	5.91
27	2	0	1	0	0	0	0	1.49	1.20	.83	0	0	3.25
27	3	1	0	0	0	0	0	1.00	1.00	.91	0	0	5.25
27	4	0	1	0	0	0	0	.51	.68	.67	0	0	6.63
27	5	1	0	0	0	0	0	1.00	1.00	1.25	0	0	4.95
27	6	2	0	0	0	0	0	.75	.80	1.00	0	0	6.37
27	7	1	0	0	0	0	0	1.33	1.12	1.25	0	0	3.96
27	8	2	0	0	0	0	0	1.00	.88	.96	0	0	5.70
27	9	0	1	1	0	0	0	.41	.84	.62	0	0	8.02
27	10	2	0	0	0	0	0	.80	.67	1.00	0	0	6.52

ASSIGN GARRIDC CM1 TO USS OSCAR 23 4 10.746

W VECTOR AND UTILITY OF GARRIDO QM1 FOR ALL SHIPS

23	1	0	1	1	0	0	0	.05	.09	1.48	0	0	9.53
23	2	0	0	1	0	0	0	1.00	1.00	.52	0	0	6.74
23	3	1	0	1	0	0	0	1.00	1.00	1.00	0	0	6.58
23	4	0	1	1	0	0	0	.05	.09	.09	0	0	10.75
23	5	1	0	1	0	0	0	1.00	1.00	1.00	0	0	6.58
23	6	0	1	1	0	0	0	.05	.09	1.48	0	0	9.53
23	7	2	0	1	0	0	0	1.95	1.91	1.48	0	0	2.50
23	8	0	1	1	0	0	0	.05	1.00	1.00	0	0	8.18
23	9	0	0	1	0	0	0	.05	1.00	.52	0	0	8.90
23	10	0	1	1	0	0	0	1.00	1.00	.52	0	0	6.44

ASSIGN WENGER R BM2 TO USS KILO 28 2 8.830

W VECTOR AND UTILITY OF WENGER R BM2 FOR ALL SHIPS

28	1	0	1	1	0	0	0	.83	.83	.80	0	0	6.89
28	2	0	0	1	2	0	0	.50	.83	.54	0	0	8.83
28	3	1	0	1	1	0	0	.87	.91	.79	0	0	7.58
28	4	0	1	1	0	0	0	.75	.67	.90	0	0	7.30
28	5	1	0	1	2	0	0	1.37	1.25	.96	0	0	5.95
28	6	0	1	1	2	0	0	1.12	1.00	.79	0	0	6.58
28	7	2	0	1	0	0	0	1.22	1.25	.92	0	0	5.92
28	8	0	1	1	1	0	0	.95	.96	.72	0	0	6.79
28	9	0	0	1	0	0	0	.75	.69	.67	0	0	7.77
28	10	0	1	1	1	0	0	1.12	1.00	1.09	0	0	5.98

APPENDIX F

(AFTER ASSIGNMENT)
EDP/PCB

BM					QM					SM					
2 1	6 6	18 15	32 25	1 1	0 0	1 0	1 3	4 4	1 1	1 1	1 1	2 5	8 5	2 0	E 7 1P 7
1 1	4 6	8 6	16 11	0 1	0 0	1 1	1 1	3 4	0 1	1 1	1 1	1 2	4 6	3 2	E11 1P11
2 2	6 6	15 14	19 15	0 2	0 0	1 1	1 1	4 8	1 0	1 1	1 1	1 4	6 6	1 0	E 5 1P 5
1 1	2 2	4 3	6 6	0 2	0 0	1 1	0 0	1 1	0 2	0 0	1 1	1 2	1 1	0 0	E15 1P15
1 1	4 4	8 11	16 12	0 1	0 0	1 1	1 1	3 4	0 0	1 1	1 1	1 3	4 5	3 0	E12 1P12
1 1	4 3	8 9	16 10	0 1	0 0	1 1	1 3	3 3	0 2	1 1	1 1	1 2	4 5	3 2	E10 1P10
2 1	6 8	18 22	32 24	1 3	0 0	1 2	1 1	4 3	1 3	1 0	1 2	2 3	8 6	2 0	E 8 1P 8
2 1	6 6	19 18	31 19	1 9	0 1	1 0	1 2	4 3	1 5	1 0	1 0	2 4	8 7	2 1	E 6 1P 6
1 3	5 4	8 7	13 10	1 1	0 1	1 0	1 1	3 4	0 0	0 1	1 1	2 3	4 4	2 1	E 4 1P 4
1 1	5 5	8 9	13 14	1 1	0 0	1 1	1 0	3 6	0 1	0 0	2 1	1 3	4 7	3 0	E 2 1P 2

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3. REPORT TITLE

A MODEL FOR AUTOMATION OF PERSONNEL ASSIGNMENT

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Thesis

5. AUTHOR(S) *(Last name, first name, initial)*

Blatt, Russel N. and Cass, Dudley E.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October, 1966	111	18

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

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13. ABSTRACT

This thesis demonstrates the feasibility of computerized assignment of Naval enlisted personnel to fleet units. A model is constructed for determining the utility of each man for each possible ship assignment. Then various methods of assignment are investigated to find one which maximizes the summed utilities of assignment. To illustrate its capabilities, the model is then applied to several sample sets of men and ships. The authors conclude that a model of this type should be implemented in the Navy's personnel distribution system.

DD FORM 1 JAN 64 1473

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